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OIL, GAS AND PETROCHEMICAL PROCESSING

Petroleum Refiner

MAY
1959

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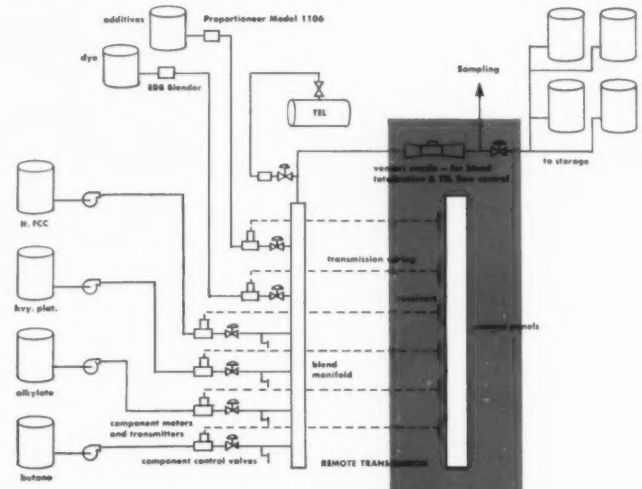

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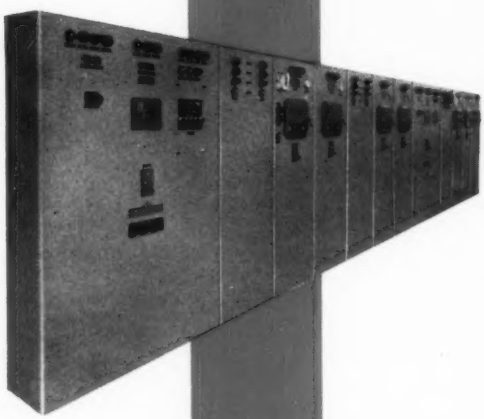

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Petroleum Refiner

OIL, GAS AND PETROCHEMICAL PROCESSING

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SPECIAL REPORT ON NATURAL GASOLINE

☐ **Kerosine as Absorption Oil—How Good?** . . . Most plants should lower the molecular weight of absorption oil. Here's how kerosine increased production and circulation in one plant. **Page 144.**

☐ **Process Natural Gas by Permeation? . . .** It can be done effectively through polyethylene film, this study shows. Apparatus is comparable to a tube-in-shell heat exchanger. **Page 147.**

☐ **Flexible Compressors with Piston Pockets** . . . Phillips saved a lot of money by putting clearance pockets over in 1000 pistons. Compressors can then handle changing suction pressures and engines can be kept fully loaded. Turn to **Page 151.**

☐ **Operators' Handbook for Gasoline Plants** . . . At last, here's a primer for operators, both new and experienced, to understand the basic principles of a natural gasoline plant. It's written by plant superintendents and operating staff of Bay Petroleum and was successful with their plant personnel. Check this as a training source. **Page 155.**

☐ **Giammarco-Vetrocoke Processes . . .** These new gas treating processes from Italy overcome some disadvantages of conventional processes and improve the economics for gas streams of high CO_2 content. Turn to **Page 161.**

☐ **Setting Up Preventive Maintenance . . .** PM can be a series of headaches; but if set up right, it can be a cure. Here's how Magnolia does it in its Natural Gas department. **Page 169.**

☐ **Computing Convergence Pressure . . .** If you've been using the Hadden method for flash calculations on your computer, you'll want to look over this program. It's a way to automatically check your assumed convergence pressure. **Page 172.**

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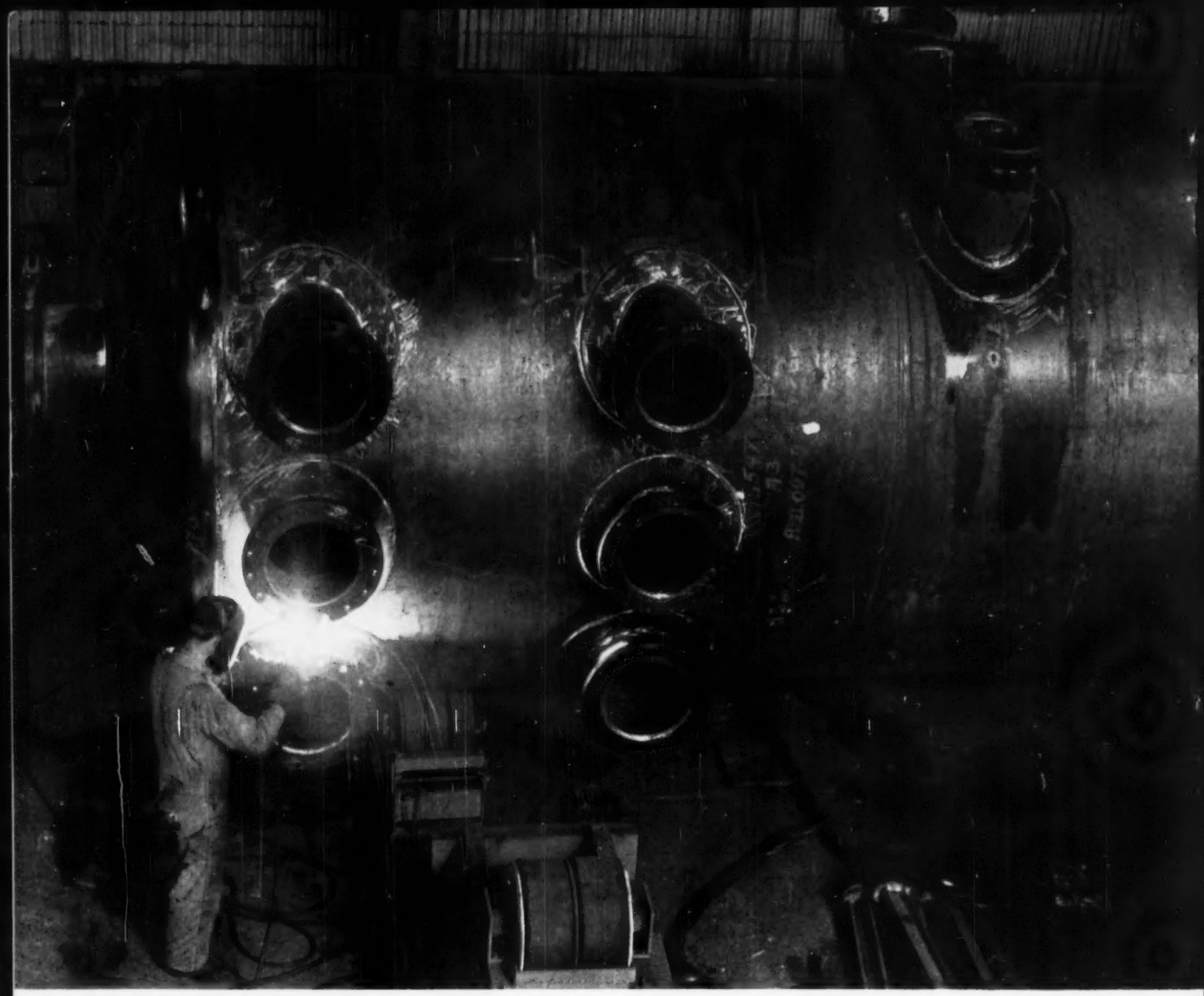

The Business End of a Big New Vessel for DOW Petrochemicals

An expanding petrochemical plant at The Dow Chemical Company in Bay City, Michigan called for an interesting two-part processing unit—a quench water tower and a quench water tank. Designed by Bechtel for the new plant now under construction by The Austin Company, this unit was awarded to Graver for fabrication.

This petrochemical unit for Dow is one of many types of both shop-built and field-erected processing equipment which Graver fabricates for the growing petrochemical, chemical and petroleum industries. In Graver's century of experience you will find the most modern fabricating and research techniques for the processing equipment you require.

Fabricated from ASTM A-285 GC Fire Box Quality Steel in accordance with ASME code standards, the tower was shop-built and the tank field-erected. The tower was constructed to withstand a design pressure of 15 psig, the tank, 3 psig. The design temperature provided for by the tower is 650°, by the tank, 200°. All welding was spot radiographed. Before leaving the shop, the tower was sandblasted and painted with one coat of lead chromate primer.

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A Quick Look at This Issue . . .

☐ **Which Acetylene Removal Scheme is Better?** . . . Absorption and hydrogenation each have a place for this duty. However, economic advantages depend on plant size, acetylene value and acetylene production. For a quick comparison, turn to **Page 177.**

☐ **API Panel Studies Corrosion Control Tests** . . . Two panel surveys reveal sloppy procedures and interpretations by refiners in making analytical tests for corrosion control. Too many are uncertain as to the significance of the test results. Complete details on **Page 181.**

☐ **Infrared Analyzer Controls Absorber . . .** Higher ethylene recovery and lower methane absorption result from this demethanizing absorber with an infrared analyzer set-up. The analyzer controls heat input to the reboiler. **Page 183.**

☐ **Control by Temperature Difference? . . .** Is this method always dependable? Under what conditions does temperature difference control work? For a lucid discussion on this method of tower control, see **Page 187.**

☐ **Heat Transfer Nomographs, Part 8 . . .** **Heat transfer coefficients for liquids and gases outside tubes** . . . Here's a long drawn-out calculation resolved into an extreme useful nomograph. Not only is it a time-saver, it will eliminate many of the errors usually associated with fractional powers. **Page 193.**

☐ **Applied Hydrocarbon Thermodynamics . . .** **Part 10B, Charts for Compressor Calculations** . . . This article includes valuable working charts along with a sample problem and a step-by-step solution to help you in these calculations. Also typical indicator cards to illustrate the effect of clearance volume on these calculations. **Page 195.**

☐ **Large Motors For Compressor Drives . . .** Squirrel cage induction motors greater than 1,500 hp are not unique for refinery compressor drives, still the application does present unique problems. This study of 29 application cases will help you avoid poor design. **Page 203.**

☐ **Rigorous Distillation Method . . .** For multicomponents with a rapid convergence and a minimum trial and error this is what you've been looking for. **Page 209.**

☐ **Estimate Gas or Liquid Viscosity Data . . .** Viscosity is a property which appears in many engineering problems. Here are some methods of correlating and estimating it. **Page 217.**

☐ **Find Heat Losses Graphically . . .** Are you wasting time doing trial-and-error heat loss and insulation calculations? Here's a series of graphs and nomographs which simplifies, shortens and gives better accuracy for this tedious task. **Page 227.**

☐ **Number of Trays vs. Reflux Ratio . . .** Here is a straight line correlation to give you the answer for the number of stages required in your distillation setup at a finite reflux ratio. This method is empirical, but will give you a fast answer with pretty fair accuracy. **Page 237.**

☐ **Reduce Cooling System Corrosion . . .** Fabrication oil films on steel tubes interfere with inhibitor adsorption on the surface. For complete details on a new recommended startup procedure, turn to **Page 239.**

☐ **Quickly Estimate Steam Plant Costs . . .** Many factors enter into the estimation of large steam generating unit costs. These are resolved into several charts for rapid estimation. **Page 243.**

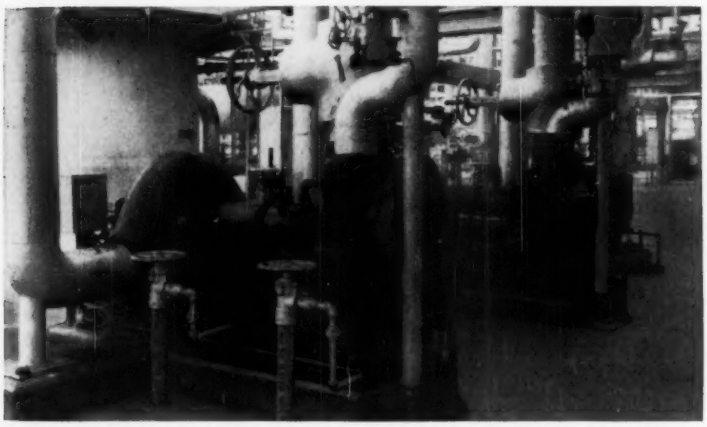
☐ **Compute Distillation Trays Rapidly . . .** For first approximations and rapid estimations this method will give you results within 5 or 10 percent of the true value of the number of trays. **Page 247.**

☐ **Find Out Why Employes Quit! . . .** One way of doing this is by conducting an "exit interview." This excellent personnel technique will reach the roots of any "hidden" personnel problem within your organization. It may also be a valuable tool in salvaging important employes who are ready to resign. **Page 281.**

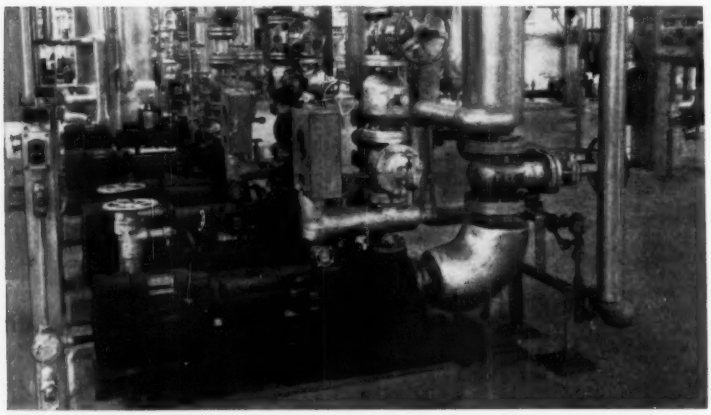
☐ **Inext Gas + Poor Piping = Explosion . . .** At 9:05 a.m., June 3, 1958, an explosion occurred at Polymer Corp. in the piping above a storage drum containing dilute butadiene. Here is what Polymer learned from that explosion, and what corrective action has been taken. **Page 285.**

☐ **Are Your Supervisors Good Leaders? . . .** Cities Service is finding the answer to this question by asking employes what they think of their boss.. It's paying off, too, for both the company and its supervisors. **Page 292.**

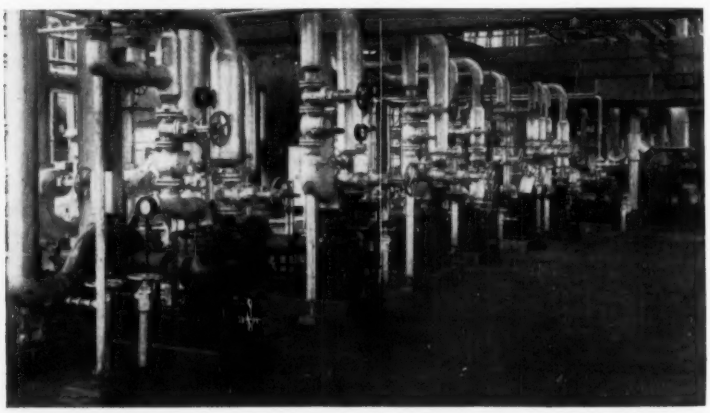
80 Wilson-Snyder ES Centrifugal Process Pumps help keep Texaco's new Puget Sound Works on stream!



Shown are heavily lagged Wilson-Snyder 2 x 3, 2-stage ES pumps handling hydrocarbons at 183 gpm and 902-feet differential head. Wilson-Snyder pumps of other sizes are available for similar services with capacities from 15 to 2000 gpm.



Ten Wilson-Snyder Pumps are in Texaco's new polymerization plant in the Puget Sound Works, the largest being the 3 x 4 x 8½ ES shown in front. Pumps in this plant handle fluids of varying specific gravities under a wide range of temperatures and pressures and have capacities from 40-400 gpm.



This installation is at the crude unit. Eleven Wilson-Snyder Pumps, both steam turbine and motor driven are in service here handling fluids with temperatures up to 691 °F. at capacities from 15 to 515 gpm.

80 Wilson-Snyder Pumps in 11 different sizes have been installed in Texaco's new, modern refinery at Anacortes, Washington. They will perform under a wide range of temperatures, capacities, specific gravities and pressures.

In spite of the varied types of service conditions, the 80 pumps do not require a large stock of maintenance parts. All 11 pump sizes can be serviced with only *three* sizes of bearing bracket assemblies, including shafts, sleeves, bearings and packing. What's more, nine other Wilson-Snyder pump sizes can also be serviced from these same three bearing bracket assembly sizes.

This interchangeability of parts means low inventory investment for overall maintenance. You, too, can save money by standardizing on Wilson-Snyder Process Pumps for all requirements within the scope of their application.

Wilson-Snyder Process Pumps are designed for applications up to 900°F., suction pressures to 600 psi, and discharge pressures to 750 psi. They are furnished in 20 sizes from 15 to 2,000 gpm, 50 to 1,100 foot head, and 2 to 250 horsepower.

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. . . on Wilson-Snyder Process Pumps can be arranged through your nearest "Oilwell" Branch . . . or direct from WILSON-SNYDER SALES ENGINEERS at . . . Chicago, Illinois . . . Dallas, Texas . . . Houston, Texas . . . Los Angeles, California . . . New York, N. Y. . . . Tulsa, Oklahoma . . . Pittsburgh, Pa.

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Oil Well Supply Division of United States Steel

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PIPE LINE INDUSTRY and The PIPE LINE CATALOG for the oil and gas pipe line industry.

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Refinery Like

IN THE "CONOCOAN" (Continental Oil Company's employes newspaper), we noted this allusion to natural gasoline plants: "those refinery-like islands in oil fields." Though refinery-like, we've always felt that the natural gasoline plant man deserved a special look each year. In this issue, you'll find what's happening in plant operations, maintenance, training and processes. You'll also find the highpoints of the recent NGAA annual meeting.

Plant operations remain the No. 1 problem; but new processes are now developing for gas processing. One of the possibilities is the permeation process, described in this special report. But the hottest processes going are the new carbon dioxide removal schemes. Latest to be unveiled is the Italian process, Giammarco-Vetrocoke, described for the first time in this report.

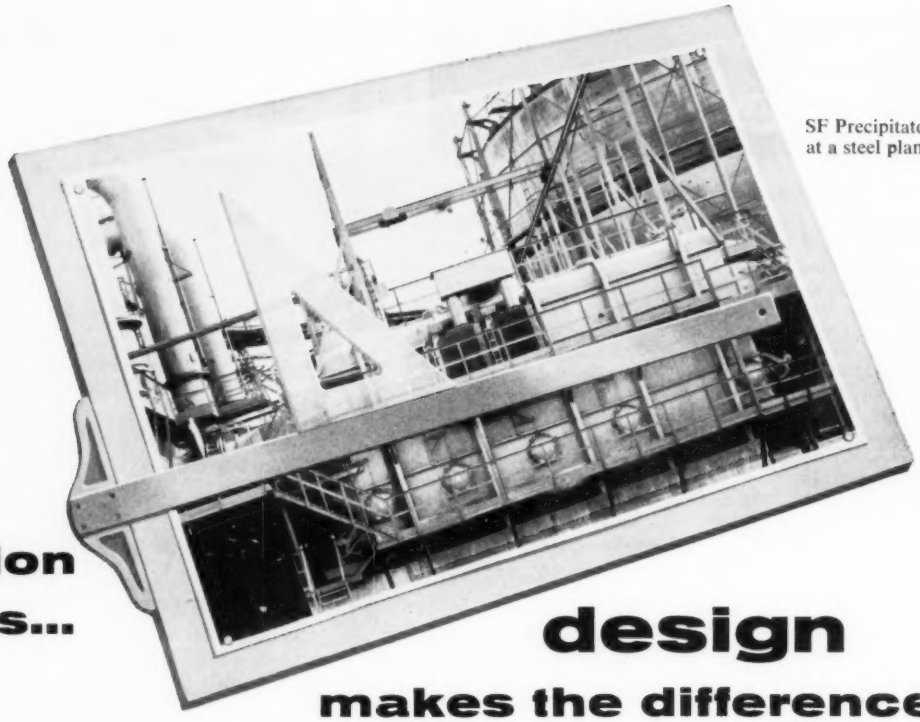
Again, "Best Ever"

MAYBE IT'S A LITTLE EARLY to begin talking about next September's contents but the staff has been enthusiastic about these possibilities since a conference which was held early in March. The conference was attended by five outstanding men from industry who contributed a lot of fine thinking that will help the staff shape the September Process Development special issue. "If the rest of our plans for the 1959 Process Issue go as well as did our recent editorial conference, we can say right now that the issue will be the best ever." That's the comment from Harold L. Hoffman as contained in the report of the March conference. "This conference tells us that our staff ideas are shared by industry people," he continued. "The big contribution comes from the ideas added to our present list of priority subjects. With this excellent industrial help we are now saddling up for the big fall roundup called 'PETROLEUM REFINER Process Developments Issue'."

Award for Safety

BECAUSE OF PETROLEUM REFINER's fine record in the presentation of material relating to better safety practices in the oil, gas and petrochemical processing industry, the National Safety Council has named us as recipient of one of its Public Interest Awards. The award was based on articles published in 1958 but that period is but typical of the many years we have been hot on this most challenging topic. These safety awards were established to recognize and honor exceptional service to safety in the public information field. "Performance well above the average, qualitative as well as quantitative," the notification explained, "leadership, initiative and originality. It means a continuous—not a sporatic—effort."

However, above and beyond the pride which naturally accompanies such recognition, is an even better feeling that comes with the knowledge that through our efforts, PR almost certainly has helped prevent many accidents.



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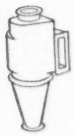
Higher efficiency of Buell 'SF' Electric Precipitators is the result of exclusive engineering features. For example, Buell's *Spiralectrodes* emit 50% to 100% more electrons than other types . . . and *maintain* their efficiency. Positive gas flow control through adjustable baffles prevents scouring and eddying. And Buell's Unique Continuous Cycle Rapping practically eliminates "puffing".



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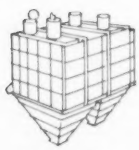
Lower installation cost of Buell's time-proved simplified design makes erection faster and easier. Spiralectrodes, for example, are self-tensioning, require no weights. Flexibility of power supply means easier installation, operating safety.



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Lower maintenance cost is the result of many details of superior design. And sectionalized design permits shutting down part of a unit without interrupting service in the rest of the unit.

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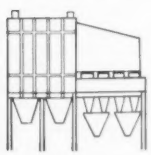

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Quick Look at Industry...

Refiners Facing Gasoline Glut . . .

Refiners starting to cut-back crude runs to avoid oversupply of products. D-X Sunray president R. W. McDowell says industry running one million bpd more than at same time in '58--yet "no justification for doing so."

Here's quick run-down on refinery cuts so far: Conoco, 10,000 bpd in Mid Continent with another 9,000 bpd slated this month; D-X, 10,000 bpd at two Oklahoma plants; Suntide,11,000 bpd at Corpus Christi; Pure, 3,000 bpd at Chicago; Esso Standard, 25,600 bpd; Delhi-Taylor, 11,000 bpd; Amoco, 10,000 bpd at Texas City. Probably more to follow.

Over-all Picture Looks Bright . . .

In spite of few dark areas, improved demand and firming prices assure U.S. producers and refiners of good market in '59 according to recent investment survey. International companies still face U.S. imports restrictions, higher foreign taxes, overproduction and lower crude prices. However, they control European and other marketing outlets abroad --thus can "play off" one foreign producing area against another. Result: substantial profit potentials for all internationals.

States Report Tax Totals . . .

States collected $2.919 billion in motor fuel taxes in 1958--up 3.2% from '57. California led, with Texas second and Pennsylvania third. Others in the $100 million and over class: Ohio, New York, Illinois, Michigan, and Florida.

More Demand for Heating Oil? . . .

"Yes," say distributors who claim more rigid specs will hike demand for No. 2 heating oils. Present gravity range much too wide--makes consumer burner design expensive. One step asked: raise commercial standard for minimum gravity from present 26° API to 32.

Teamsters Accuse Esso Management . . .

Teamsters claim investigator for Senate Rackets Committee tried to convince president of Independent Petroleum Workers Union at Bayway, not to affiliate with Teamsters. Says investigator was acting "for and on behalf of" Esso. Company denies charges.

Mid-East Oil Politics Getting Hotter . . .

At first Arab Petroleum Congress in Cairo, oil politics got more attention than technical matters. Abdullah Tariki, chief of Saudi office of Petroleum and Minerals, contends, "It's only a matter of time before we get the same 60-40 split that the Venezuelans announced in December."

But Tariki's not out to just nationalize oil industry--Mossadegh did that in Iran only to find he couldn't sell oil. Instead, Tariki is still aiming for ""integrated" operations with Arabs taking share in all phases of producing, refining, and marketing.

Latest Octane Postings . . .

Motor fuel ratings held steady last month according to latest Ethyl survey. Premium clung to 99.1 F-1 while regular continued to toe the mark at 91.7 F-1.

One significant point: although octanes rose during '57-58 period, use of TEL decreased 15%. Reason: more octanes furnished by reforming, alkylation, etc. But look for more TEL use later.

Oil Big Radioisotope User . . .

Oil accounts for almost one-third of money saved by industry through use of radioisotopes according to National Industrial Conference Board. Refiners alone save $11.6 million annually.

On the Bargaining Scene . . .

New employe benefit just beginning to show at bargaining tables: dental health care insurance. Hasn't appeared in oil or petrochemical industry yet, may bear watching.

U.S.S.R. Finally Settles DuPont Claim . . .

Russia pays DuPont $1.5 million settlement for claim filed in 1955. Stems from war-time agreement which saw DuPont give Soviets technical information on producing neoprene. After war, Russia wanted plant built, but got cold shoulder because of cold war.

Some say settlement made only as part of over-all Soviet plan to boost foreign trade. Along these lines, Oklahoma professor sounds warning that Soviets trying to dump laboratory equipment in this country to gain entrance to vulnerable academic circles. Claims one American company already placed order for $45,000 worth of such instruments--at about one-third the cost of comparable U.S. equipment.

More Mergers on Oil Scene . . .

Sun Chemical sells subsidiary, Warwick Wax, New York, to new company--Western Petrochemical. Warwick has refinery at Chanute, Kas . . . Skelly and Tidewater considering merger--but nothing definite yet . . . Sunray Midcontinent and Suntide Refining trying again to merge--similar plans last year cancelled when holder of big block of Suntide stock objected . . . Conoco makes offer to buy International Refineries and Western Oil & Fuel.

Quick Look Around the Country . . .

BuMines tags amount of U.S. crude to be consumed or exported in May at 7.19 million bpd . . . Texaco to build 2,050-bpd sulfuric acid alky unit and 600-bpd butane isom unit at W. Tulsa plant--both slated for November completion . . . Columbia Gas "actively seeking" chemical companies to build adjacent to Columbia Hydrocarbon plant at Siloam, Ky. Needs outlet for potential ethylene production.

On the Air Pollution Front . . .

Shell starts-up carbon monoxide boiler at Wilmington-Dominquez plant. Steam from waste gas boiler costs more, but extra dollars assure air pollution control.

More Petroleum in Sight . . .

Proven reserves rose in '58 says annual joint report by API and AGA. Present status: crude at 30.5 billion barrels—up 235 million from '57; natural gas liquids at 6.2 billion barrels—up 517 million; natural gas at 254 trillion cu. ft.--up 7 billion.

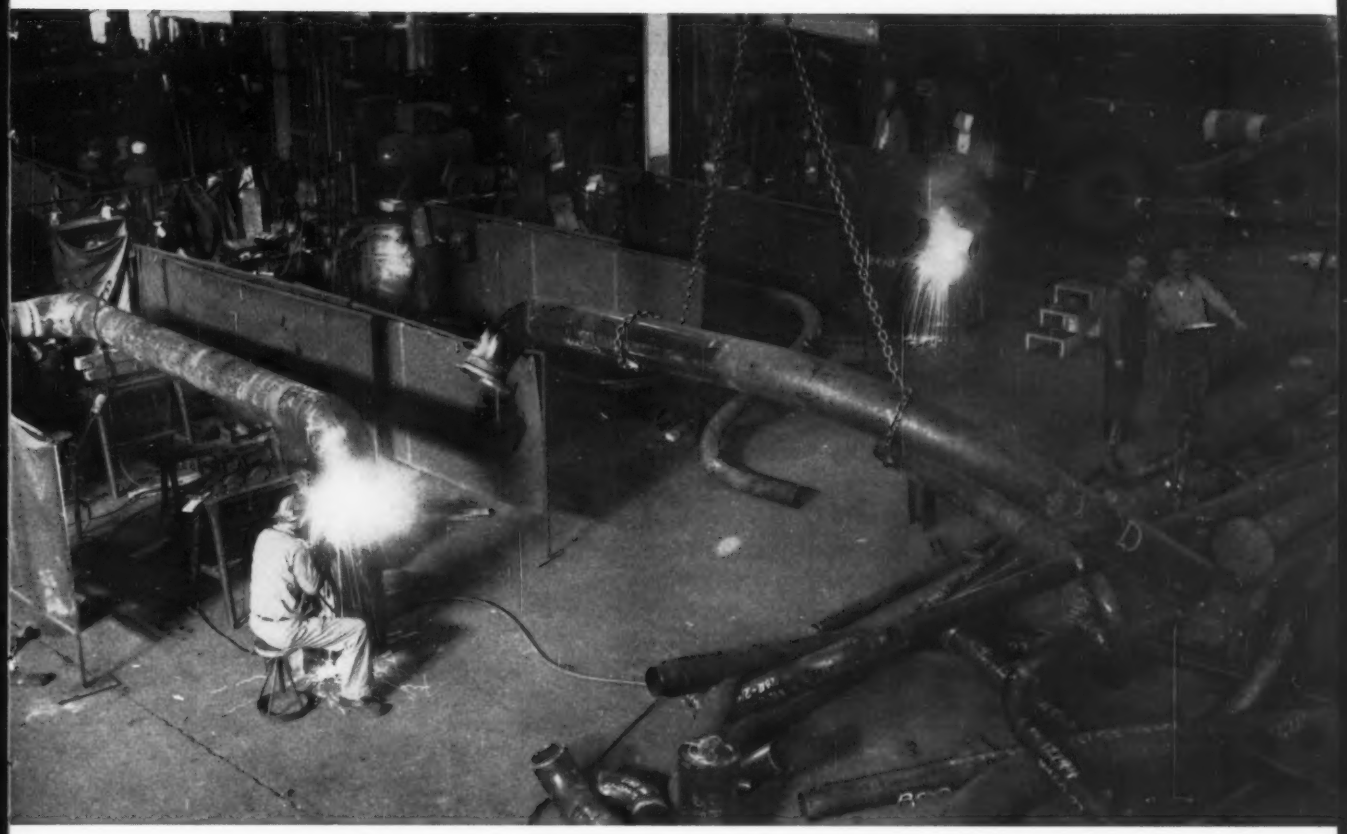
Computer Does Whole Job . . .

First completely computer-controlled processing now on stream at Texaco's Pt. Arthur refinery. Previously, computers just furnished data which operators used to set conditions. Now, digital maintains control points on polymerization unit. More computer control coming say Goodrich and Monsanto.

Jet Fuel Needs to Zoom . . .

Military and commercial jet fuel needs to top 500,000 bpd by 1965 says recent NPA meeting. At that rate, jet fuel will triple today's avgas market. Future jet fuel will likely be wide-cut (JP-5)--combined kerosine and gasoline fractions.

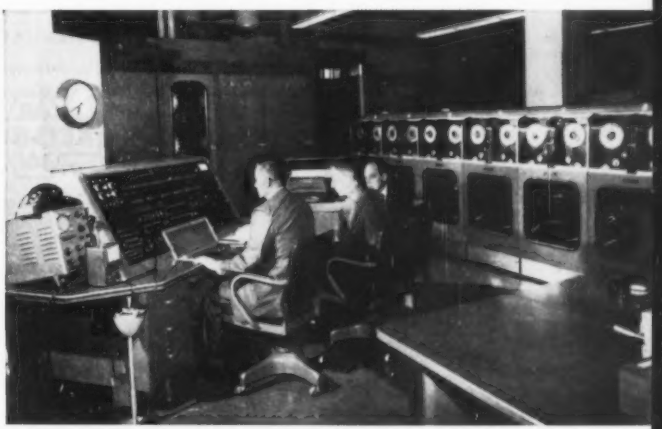
How Blaw-Knox cuts your power piping costs



121,000 square feet of space at your service. Power piping facilities at Pittsburgh include 56,000 square feet of plant area and an additional 65,000 square feet for exterior storage. An additional new plant is located on a 15-acre site in Jackson, Mississippi.

Your job is under the personal supervision of an experienced engineer, who follows your project from beginning to end. Your piping is handled with the most modern equipment for welding, heat treating, and bending. Fabricating techniques, proven by rigid testing, are used.

New product development. Blaw-Knox developed an enclosed type of functional spring hanger as part of their complete line of hangers for supporting any piping system. Here a group of hangers individually designed for a project is factory checked to assure fast field erection.



Stress calculation cut from months to a day . . . with pace-setting engineering. An exclusive Blaw-Knox method uses an electronic computer for automatic computation with no limitation on the complexity of system. Full accuracy, with tremendous savings in time and cost. Write for details.

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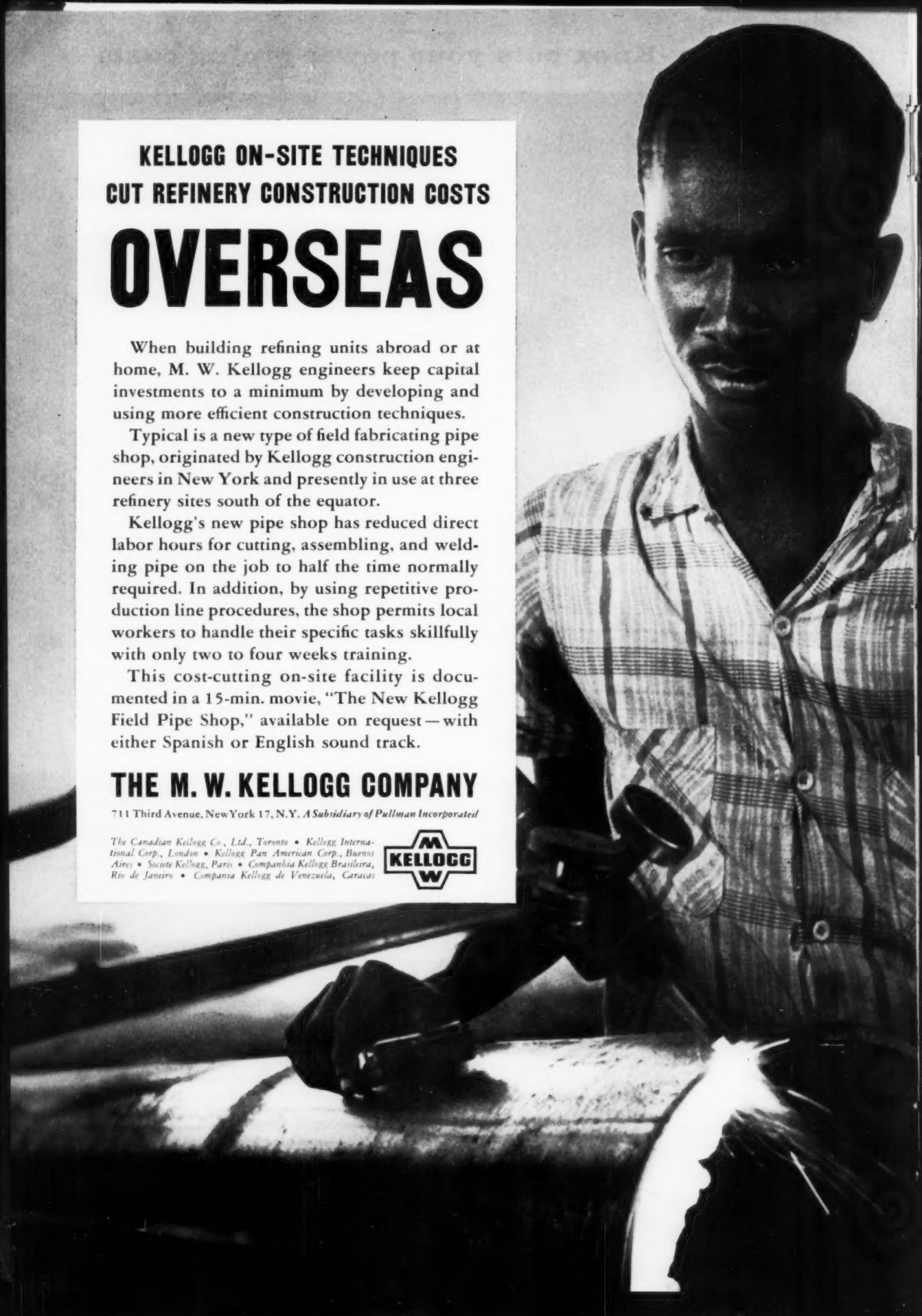
BLAW-KNOX COMPANY

Power Piping Division

829 Beaver Avenue, Pittsburgh 33, Pennsylvania



KELLOGG ON-SITE TECHNIQUES CUT REFINERY CONSTRUCTION COSTS

OVERSEAS

When building refining units abroad or at home, M. W. Kellogg engineers keep capital investments to a minimum by developing and using more efficient construction techniques.

Typical is a new type of field fabricating pipe shop, originated by Kellogg construction engineers in New York and presently in use at three refinery sites south of the equator.

Kellogg's new pipe shop has reduced direct labor hours for cutting, assembling, and welding pipe on the job to half the time normally required. In addition, by using repetitive production line procedures, the shop permits local workers to handle their specific tasks skillfully with only two to four weeks training.

This cost-cutting on-site facility is documented in a 15-min. movie, "The New Kellogg Field Pipe Shop," available on request—with either Spanish or English sound track.

THE M. W. KELLOGG COMPANY

711 Third Avenue, New York 17, N.Y. *A Subsidiary of Pullman Incorporated*

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M KELLOGG W

The Futility of Outlawing Cudgels

ONCE UPON A TIME a group of men banded together for survival. Clothed in leopard skins and sleeping in caves, they stayed together because, singly, they were no match for the animals which roamed nearby.

Then one day a strange thing happened. A few of the more ingenious members of the group found that stones lashed to sticks made very formidable weapons. Armed with these new tools, only a few of the group were needed to fight off the marauding animals, capture food, and satisfy all of the needs for existence.

You can imagine the uproar which followed. Those who had not yet fashioned tools gave forth with many grunts and ughs. Literally translated, they said, "Why, those men with clubs no longer need our help. Those terrible clubs are taking our jobs. We certainly must get laws passed to prohibit their use!"

But the law was vetoed. Man has grown to become very dependent upon the tools he has fashioned. Now the number, size, and complexity of these tools are almost unbelievable. They form a backbone for all of the mechanized operations we practice today.

And yet, there still are men who say, "Look out for machines. Those terrible things are taking our jobs."

Our technological progress is facing many opponents. In a recent talk before a meeting of the Society for the Advancement of Management, Charles H. Thayer, vice president of manufacturing for Sun Oil Company, places the blame on both management and labor.

On the labor side of the industry, Mr. Thayer tells of Walter Reuther's warning that a push-button factory production threatens the nation with mass unemployment. Reuther's predecessor, Philip Murray, proposed congressional regulation of the introduction of large technological changes.

"While some union leaders were busy persuading employes to resist every change," Mr. Thayer reports, "management in many plants permitted the problems to pile up until the accumulation of resulting inefficiencies could be tolerated no longer. Then there came a labor upheaval, perhaps, or a complete shutdown or abandonment of a plant, or a reorganization in which hundreds or maybe thousands of men were laid off."

As for management, Mr. Thayer claims it "has been derelict in its responsibility to communicate with and inform the working man. I will go further," he says, "and state that I believe management's greatest failure has been in the field of human relations . . . We in industry are all guilty, to a greater or lesser degree, of being so preoccupied with the economics, the finances, the developments, the installations and efficient operation that we have often failed to take our employes into our confidence."

Mr. Thayer tells us our competitive system will demand the use of more mechanized operations. Thus man must be challenged to exercise his own special talents to a greater degree than is done today.

Man is the most complex machine. When we talk about the push-button machines of the future we must remember the most complex machine of all is MAN. Yet it is man's versatility which makes him so valuable, not his highly developed specialization of manual skills.

Man must strike out for new and varied horizons. Machines can only help make the progress faster and easier.

A continuous evaluation is needed. Organizations and individuals alike are required to make a continuous evaluation of their purpose and qualifications. Organizations such as corporations making obsolete products are penalized by probable bankruptcy. In like manner, individuals choosing to perfect unneeded skills are destined for the bread line.

Of course, our society will make allowances for these unfortunates. But a whole industrial system based on obsolete skills and practices can not survive. We must spur the individual into improvement.

Promotions, new duties, and higher pay are not compensation for age. They are the reward of progress and development.

We must answer many questions:

- Why do I need more schooling?
- What job will pay me the most?
- What do I need to know to succeed?
- What is my future with this company?
- Why didn't I get a bigger pay raise?
- Why can't I find another job?
- Why can't I afford early retirement?

So goes a lifetime of questions. And the answers

CHROME MOLY

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WE CARRY LARGEST STOCK OF LOW AND INTERMEDIATE CHROME MOLY PIPE ½" THROUGH 20"; SEAMLESS WELDING FITTINGS 2" THROUGH 14" —AND FORGED ALLOY FITTINGS ¼" THROUGH 2".

A portion of the large and varied Pipe Stock that we carry for prompt shipments.

Our unusual familiarity with the "piping requirements" of the Refining and Petro-Chemical Industries, as well as the Piping Fabricator and Contractor—plus the fact that we carry the largest stock of Chrome Moly Piping Materials —all work to your advantage. Of course, Capitol also assures you of the Highest Quality, Right Price, and Courteous Service.

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to our daily questions are seldom fixed—they depend on the times. In this machine age, the rate of progress is much faster so that the proper answers change all the quicker.

Greater productivity afforded us by machines gives us more time to prepare for tomorrow—more time to learn and understand. If we fret away this opportunity, we can certainly expect to pay the penalty.

As the world spins by, we will be left in its dust, and no amount of proposed legislation will call back "those good ole horse and buggy days."

Billion Bundle Pure Bunk!

OF THE MAJOR WAGE CONTRACTS on file with the Department of Labor, 154 will come up for negotiation this year. These contracts will cover many phases of industry and will involve about 4.5 million workers. Certainly one of the largest and most powerful is the Steel Workers Union, with its 1.25 million members, whose contract expires on June 30.

Now, we have no doubt that the unions will come up with a "package" deal comprising the usual higher wages and benefits. However, in this case, the Steel Workers Union is not talking in terms of a mere package—it's talking about a billion dollar bundle!

No doubt you've seen the advertisements which this union has been running in the newspapers, telling about how an extra billion dollars in the pockets of steel workers will increase the sales and profits of the auto industry, the moving picture houses, and the home builders of America, and so on ad infinitum. Just from reading these ads, one gets the idea that those persons heading the Steel Workers Union are just about the best friends the people of America have—they're going to do the whole nation a great favor by getting that "billion dollar bundle" for us all.

But you know, there are some awfully short sighted people in this old world. For example, Robert C. Tyson, chairman of United States Steel Corporation's finance committee claims:

> "If a group of people gets a billion dollars more, they will spend more—no argument. If a group of people gets a billion dollars less, they will spend less—again, no argument. There is no way for the Steel Union group to get an unearned billion dollars more without others undeservedly getting a billion dollars less—except that an additional billion dollars be, in effect, printed up, and this is pure inflation. But if one gets more and another gets less, the total is unchanged. The notion that, by robbing Peter to pay Paul, the real purchasing power of Peter plus Paul will be increased is, in the vernacular, pure bunk."

In looking at these two points of view, there is no doubt that the Steel Workers plan certainly sounds better, but why should they be so selfish about it? Why limit it to the 1.25 million steel workers? Why not do the same for all of the 65 million gainfully employed people in America and thus raise the ante to $52 billion? In short, why not go on a real inflationary bender while we're at it? It should be lots of fun . . . while it lasts!

Point of No Return

QUITE A FEW STATES are in serious, not to say desperate, financial straits, but the current state of Michigan seems to be one of the saddest of the lot.

According to one report, Michigan is so broke it has practically banned travel by its officials to other states. Recently a number of business firms agreed to pay millions of dollars of taxes in advance, enabling the state to meet some back payrolls. Legislators sweat over what new tax bites they can take out of the citizenry. It's said Governor G. Mennen Williams' office rug is so threadbare it is being patched up with black tape, which is heartbreaking!

So what elaborate form of monkeybusiness reduced the state to this condition? Basically the answer is simple. In line with the philosophy espoused by Mr. Williams and another prominent Michigan welfare-stater, Walter Reuther, the state has tried to do too much in the way of political "benefits" with too little regard to its capacity to pay.

Interestingly enough, Mr. Reuther has lately been urging Washington legislators—and he has plenty of eager listeners in the new Congress—to do much more. That is, spend much more. And he contends that if Washington only will do that, all problems, including financial ones, will be solved.

Somehow, though, the wonderland economics haven't worked out in Michigan or a number of other states with similar ideas. There is, after all, a point of no return; just like people, governments can go busted. Small governments, medium-sized governments and even great big governments.

The above editorial is from "Review and Outlook," The Wall Street Journal, of Tuesday, March 3, 1959, and is reproduced here by special permission of that periodical.

Many times we have heard of the inconsistencies of the American people. As a matter of fact we even make fun of ourselves when we talk about boiling water for tea, then putting ice in it. Next comes sugar to make it sweet and lemon to make it sour. Ranking along with these is a situation which exists in Washington today. Ironic as it may seem we have thrown cold water on American oil investments abroad through the mandatory oil imports recently imposed. Yet at the same time, general business support is being sought for H.R. 5—the Foreign Investment Incentive Act of 1959. This measure introduced in Congress by Representative Hale Boggs, is intended to "encourage investment abroad and thereby promote American industry and reduce government expenditures for foreign economic assistance . . ." This might be compared with helping a man up with one hand and slapping him down again with the other.

How to handle TEL susceptibility in linear programming of gasoline blending studies

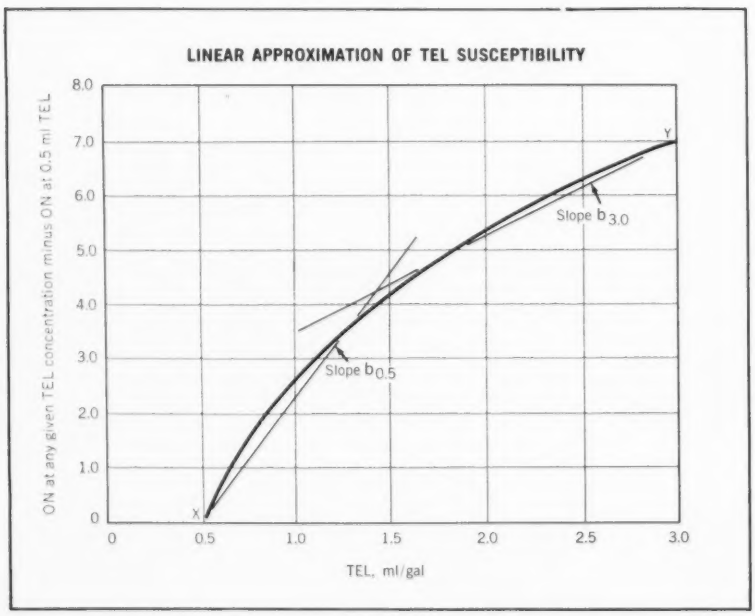
By Dr. W. C. Healy, Jr., Supervisor of the Mathematical Analysis Section,
Refinery Technology Division, Ethyl Research Laboratories

In past years, gasoline blending was comparatively simple. An engineer could establish optimum blends for two grades of gasoline by using a slide rule and a TEL response chart.

Today gasoline blending and establishing maximum antiknock effectiveness are much more complex. Many components are used to make numerous grades of gasoline. Often, market conditions divert some gasoline component to another product. All this presents the refiner with a giant-sized problem of blending for maximum profit.

The magnitude of the problem has forced the refiner to electronic computer solutions, using such techniques as linear programming.

Because TEL susceptibility is a non-linear function, it presents a special problem for computer studies when linear programming is used. Many suggestions have been made for handling the TEL function, and one of the simplest recorded to date is outlined here.



The Ethyl method of handling the TEL function is similar to others in that a target TEL susceptibility curve is approximated by straight-line segments having fixed slopes. However, it is easier to use because—

A. No extra variables are introduced.

B. No extra upper-bounding conditions are required.

C. Set-up time is reduced.

Calculating TEL linear approximations is not difficult when final blend TEL susceptibility* is known. It becomes difficult when susceptibility is to be determined by computer. Calculations must employ approximated susceptibility values while retaining accuracy for reasonable deviations.

*TEL susceptibility is here defined as the difference between octane numbers at 3.0 ml. TEL/gallon and at 0.5 ml. TEL/gallon.

For more data on advertised products, use Readers' Service Cards, last page.

Here's How Ethyl's Method Works

For example, in the figure, two line segments are used to approximate the curve. The procedure is as follows:

A. Estimate a blend TEL susceptibility curve and then plot on rectangular coordinate paper.

B. Draw two approximating lines so that one line passes through point X (0.5, ON at 0.5) and the other line passes through Y (3.0, ON at 3.0).

C. Determine the slopes of these approximating lines, $b_{0.5}$ and $b_{3.0}$, as shown on the accompanying chart.

Then the following inequalities are required; they state that the ml. TEL per gallon shall be no less than that required on either line segment, and no greater than 3.0.

1. $\text{TEL} \geq \dfrac{\text{ON (specification)} - \text{(ON at 0.5)}}{b_{0.5}} + 0.5$

2. $\text{TEL} \geq \dfrac{\text{ON (specification)} - \text{(ON at 3.0)}}{b_{3.0}} + 3.0$

3. $\text{TEL} \leq 3.0$

Let

$X_1, X_2 \cdots X_n$ = Barrels of each component in the blend.

ON_i at 0.5 = Corresponding octane blending values at 0.5 ml. TEL/gal.

ON_i at 3.0 = Corresponding octane blending values at 3.0 ml. TEL/gal.

And $Y = (\text{TEL})(\Sigma X_i)$

Then substitute in 1 and 2 above

$$\text{ON at } 0.5 = \frac{\Sigma X_i\,(ON_i \text{ at } 0.5)}{\Sigma X_i}$$

$$\text{ON at } 3.0 = \frac{\Sigma X_i\,(ON_i \text{ at } 3.0)}{\Sigma X_i}$$

and multiply 3 by ΣX_i

These inequalities then reduce to the required linear expressions:

4. $\Sigma X_i\,(\text{ON spec} - ON_i \text{ at } 0.5 + 0.5\,b_{0.5}) - b_{0.5}\,Y \leq 0$

5. $\Sigma X_i\,(\text{ON spec} - ON_i \text{ at } 3.0 + 3.0\,b_{3.0}) - b_{3.0}\,Y \leq 0$

6. $Y - 3.0\,\Sigma X_i \leq 0$

Under certain conditions the number of inequalities may be reduced to two.

Susceptibility Changes Are Compensated

Error-compensation is a built-in feature with this method since, when blend susceptibility varies (higher or lower) from the estimated value, the line segments adjust themselves to the proper portion of the new curve.

For greater accuracy, more than two line segments may be used to approximate the susceptibility curve. This requires additional analogous inequalities, but no additional variables.

Each additional octane specification calls for an estimated susceptibility curve and the statement of inequalities as shown above.

Checking the Program Before the Computer Run.

How Ethyl Research is helping you

Ethyl Research has several years' experience with linear programming as it applies to gasoline blending. This background has been especially valuable for customer service work.

The new method of handling tetraethyllead susceptibility is one example of the professional assistance available to the refiner from Ethyl.

In addition, the Mathematical Analysis Section in our Refinery Technology Division will be glad to share its experience in computation techniques with your people.

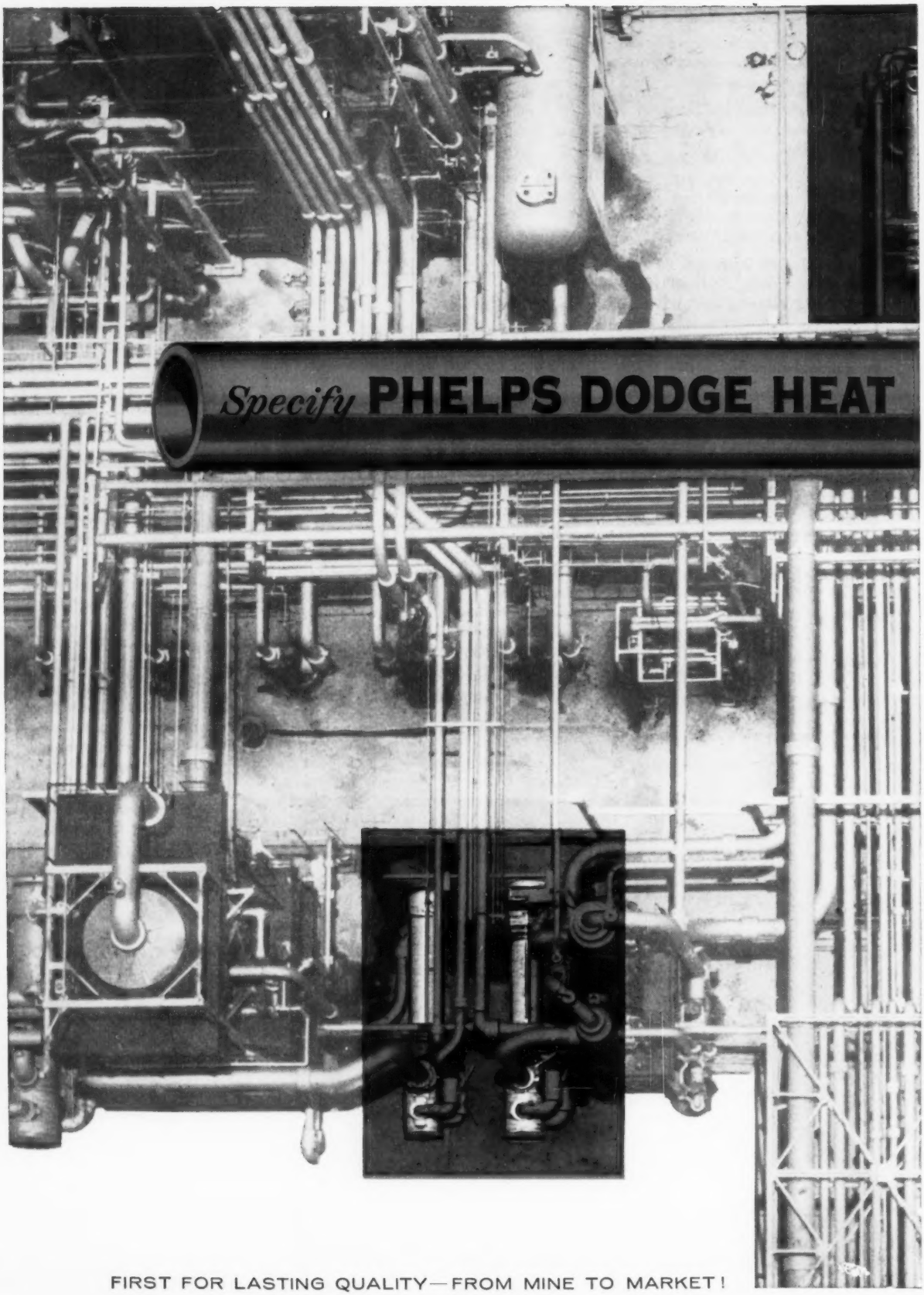
For further information, just call your Ethyl Representative. He'll be glad to arrange an appointment for you with one of our Mathematical Analysts.

ETHYL CORPORATION
New York 17, N. Y.

ETHYL ANTIKNOCK COMPOUND — ETHYL CORPORATION

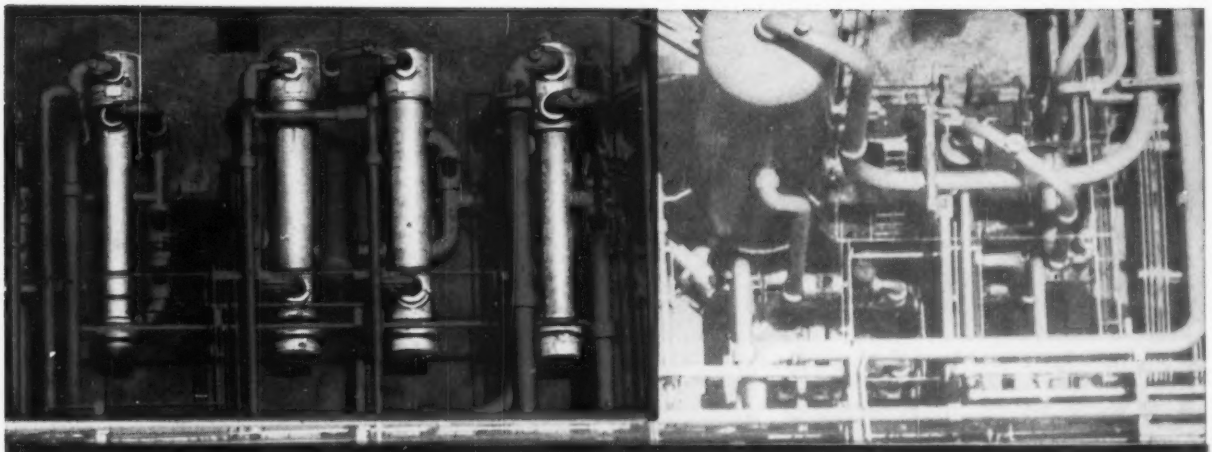
RESEARCH LABORATORIES:
1600 W. Eight Mile Road, Ferndale 20, Mich.
2600 Cajon Road, San Bernardino, Calif.

For more data on advertised products, use Readers' Service Cards, last page.



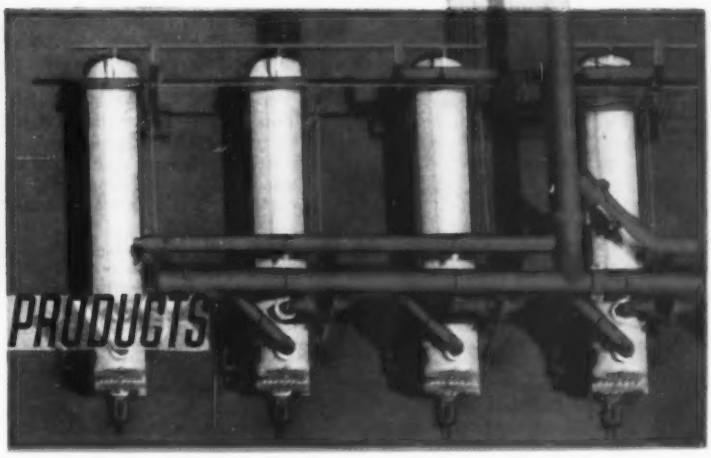
FIRST FOR LASTING QUALITY—FROM MINE TO MARKET!

For more data on advertised products, use Readers' Service Cards, last page.



EXCHANGER TUBES *for Longer Service!*

- Full range of copper-base alloys for every application.
- Vast background of application engineering to assist in proper alloy selection.
- Complete control of quality throughout every step of manufacture.

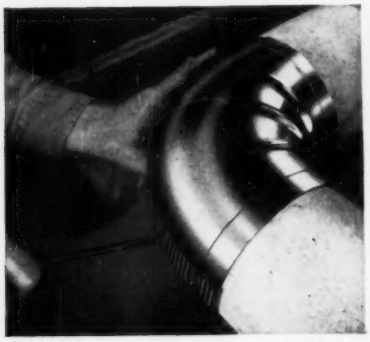


PHELPS DODGE COPPER PRODUCTS CORPORATION

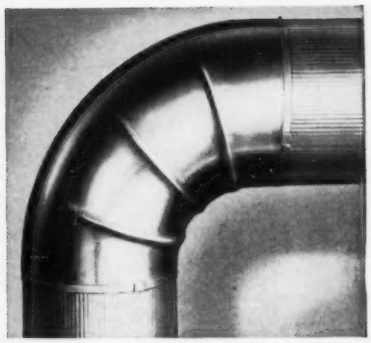
SALES OFFICES: Atlanta, Birmingham, Ala., Cambridge, Mass., Charlotte, Chicago, Cincinnati, Cleveland, Dallas, Dayton, Detroit, Fort Wayne, Greensboro, N. C., Houston, Indianapolis, Jacksonville, Kansas City, Mo., Los Angeles, Memphis, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., Richmond, Rochester, N. Y., San Francisco, St. Louis, Seattle, Washington, D. C.

For more data on advertised products, use Readers' Service Cards, last page.

9:00 A.M. Workman places two halves of Ell-Jac over insulated elbow. Halves of Ell-Jac are held in place with wire while holes are drilled for sheet metal screws.



9:04 A.M. Screws are quickly inserted to hold Ell-Jac snugly and permanently in place. Childers Aluminum Ell-Jacs come in 23 standard sizes for both 90° and 45° long radius elbows.



9:06 A.M. Ell-Jac completely installed. When straight line aluminum weather-proof jacketing is added, lines have complete, maintenance-free protection for all costly insulation.

How New Childers Ell-Jacs Save You Time and Money

Revolutionary new Childers Ell-Jacs go on fast and easy . . . fit perfectly . . . cut installation costs . . . never need painting . . . and, used with Childers Jacketing, give your insulated lines that well-dressed look from end to end.

Now, aluminum elbows are made in a wide range of sizes by America's leading manufacturer of aluminum jacketing. Childers Aluminum Ell-Jacs are available for quick, easy application to protect costly elbow insulation.

Childers Ell-Jacs are two-piece, deep drawn from .020" aluminum, #3003 alloy. They are precision-formed for long-radius elbows and come in 23 sizes for both 90° and 45° ells.

Childers Ell-Jacs, together with Childers Jacketing, now let you install maintenance-free aluminum over every square foot of your valuable insulation. You protect *all* of your insulation investment at lowest cost. You get the bonus of a better looking plant and easier housekeeping.

Positive weather-proofing with Childers Jacketing is assured by exclusive Childers Lap-Seal (Patents Pending). You're sure of getting proper lap without waste. You save labor, too.

Factory attached moisture barrier protects both Childers Jacketing and Childers Ell-Jacs against corrosion that could otherwise damage the underneath side of the aluminum. Its slight extra cost is more than offset by savings in application labor.

You also get greater strength and greater protection because Childers Jacketing is cross-crimped. Cross-crimping increases the vertical strength and rigidity of a .016" sheet to that of a plain .024" sheet.

It's easy to install Childers Jacketing. All you need are pliers and screwdriver, plus inexpensive strapping. Two men can do the job. Jacketing can be removed for inspection of the lines, then reapplied without waste.

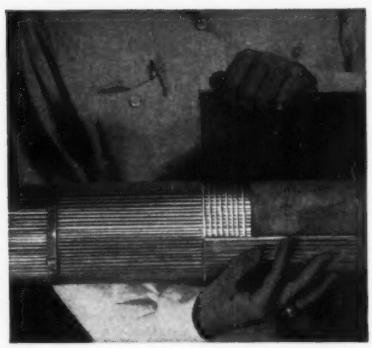
First cost is less for Childers Jacketing than for any other permanent type weatherproofing—even less than some temporary coverings.

You end maintenance worries, too, by using Childers Aluminum Weather-proof Jacketing and Ell-Jacs. Aluminum *keeps* its new look; needs no expensive periodic repainting.

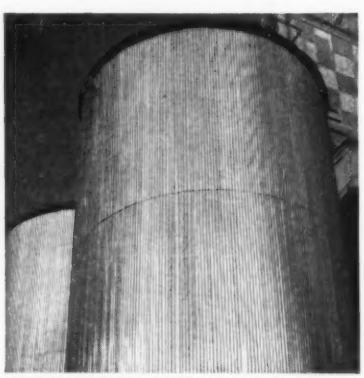
Why not benefit from Childers world-wide experience when you buy insulation for your lines, towers, vessels, and tanks? More than 2,000 petroleum refining, petro-chemical, and chemical plants will endorse your decision. Childers Engineering Representatives, located in 27 major industrial centers, give professional advice on insulation jacketing.

For a free sample of Childers Aluminum Weather-Proof Jacketing, with engineering data on how to safeguard your insulation, write Childers Manufacturing Company, Dept. PR-45, P. O. Box 7467, Houston 8, Texas.

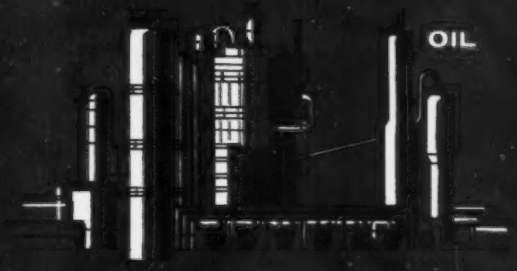
See our ad in Sweet's Industrial Construction File, Chemical Engineering Catalog and Refinery Catalog.

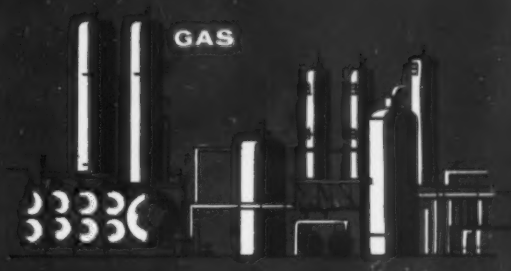


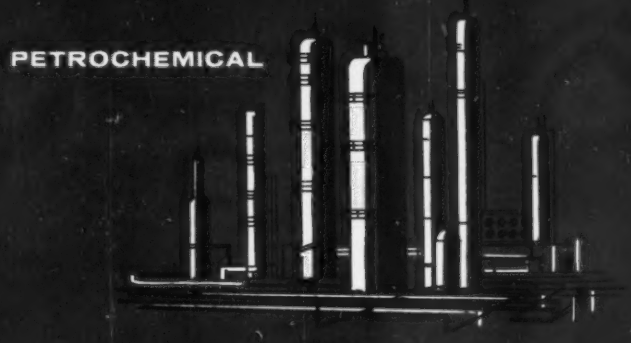
EXCLUSIVE LAP-SEAL, available at no extra cost, is a series of 8 ribs rolled into the underlapping edge of the jacketing, providing an automatic measure of the 2" circumferential lap. Proper lap is assured without waste. Labor is saved. Where desired, a positive weather seal is easily made with Lap-Seal and a mastic.

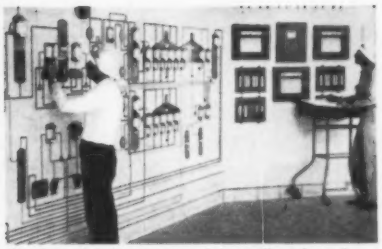


DEEP CORRUGATED Childers Jacketing in 1¼" and 2½" corrugations is recommended for permanent protection and improved appearance of insulated towers, vessels, tanks. Deep Corrugated Jacketing with factory-attached moisture barrier is another product available only from Childers.



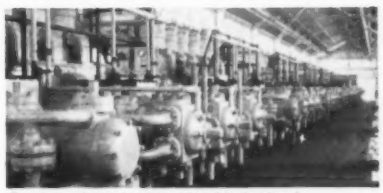






Omniguard indicating panel is easily adapted to miniaturized instrument panel installations for central control.

Detectors provide continuous temperature monitoring of drive motors for shipping pumps.



Omniguard system protects this bank of compressors installed at a natural gas cycling plant.

Oil company power plant uses Edison Omniguard system to protect generating equipment from overheating.

THOMAS A.

EDISON

omniguard system provides reliable, flexible temperature monitoring for oil, gas and petrochemical industries

Throughout your process, wherever temperature is critical, the Edison Omniguard system can protect vital equipment and output quality. It is the simplest and most flexible temperature monitoring system devised.

Plug-in detector units may be installed at key points throughout the process. They can be added or switched without disturbing the system. Typical detector locations include motor and motor bearings in shipping pumps, compressors and generating stations. Individual alarm settings on each point can be changed at any time without special tools.

Indicating panel can be located in central control room, for complete overall process monitoring by a single individual. Alarm system positively identifies trouble point.

The complete system is designed for utmost reliability. There are no moving parts, nothing to wear out.

Edison engineers will be happy to provide assistance in designing the most efficient system to meet your requirements.

For additional information write for publication 3036-C.

Thomas A. Edison Industries
INSTRUMENT DIVISION
96 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON

EDISON ENGINEERING OFFICES ARE LOCATED IN: WASHINGTON—BALTIMORE; CHICAGO; DALLAS; DAYTON; LOS ANGELES

the completely new continuous process

MOL

that removes lowest-grade hydrocarbons,

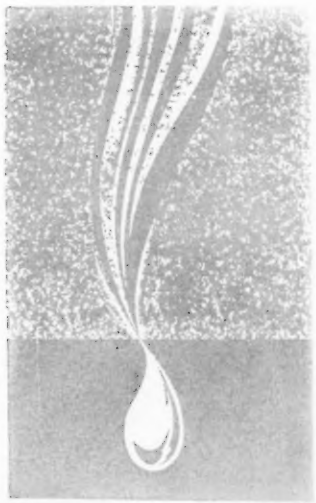
Removes normal paraffins from gasoline
Now any refiner can produce super-quality gasoline—economically! With the new continuous process, Molex, you can now accomplish what even the most severe reforming cannot do alone: Without interruption of feed and product streams, you remove normal paraffins covering the entire gasoline boiling range . . . rid your product of grossly inferior materials . . . produce the kind of gasoline that motorists want to buy!

Performs ultra-sharp separations—achieves 99% product purity
Molex separations are sharp. Product purity of over 99% is not unusual—and extended pilot plant performance proves this superior quality can be consistently maintained. Taking out virtually every trace of lowest quality components raises the "octane ceiling" on your gasoline production, substantially increases the octane number of your product.

Minimizes octane increase requirement—keeps customers satisfied
The refiner using Molex can attain his quality requirements with a cleaner

More Than Forty Years of Leadership in Petroleum Refining Technology

UOP®



MOLEX*

*TRADEMARK

purifies and upgrades gasoline

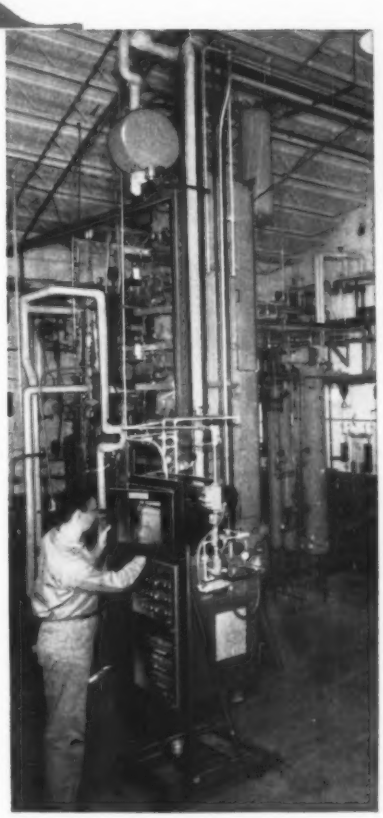
burning fuel having a minimum concentration of aromatics. Higher octane numbers are attained without high percentages of aromatics. Combustion deposits are reduced and customer satisfaction increased.

Lowers concentrations of aromatics, decreases sensitivity

Through use of Molex you attain your octane specifications with lower concentrations of aromatics. Without sacrificing yield or giving away octane number, you meet exacting sensitivity specifications, produce more versatile gasolines which will perform better under a wider range of engine and operating requirements.

Moderate initial and operating costs

The cost of installing and operating Molex is surprisingly modest—lower, for example, than in separation of normal compounds from mixtures of pentanes and hexanes. Considering the increased purity of product, decreased sensitivity, increased octane, continuous operation and other benefits provided by Molex, you will agree that here is a truly unique new process! *Write for further information.*



Part of facilities used in pilot plant stage of developing and proving Molex process.

UNIVERSAL OIL PRODUCTS COMPANY

30 Algonquin Road, Des Plaines, Illinois, U.S.A.

WORLD'S MOST MODERN REFINERY — Tidewater Oil Company's new Delaware Refinery, 15 miles south of Wilmington, represents the most advanced thinking of refinery engineers and technologists.

LOW-COST WATER AND SOLIDS REMOVAL—A BASIC FOR MANY REFINING AND PETROCHEMICAL PROCESSES

Separator/Filters have multiple uses

Applications — In today's modern refineries and petrochemical plants, many processes are highly dependent upon low-cost removal of water and solid contaminants. Fram-Warner Lewis water separator/filters are extensively employed in process applications because their use provides the benefits of improved feed preparation, reduction in catalyst consumption, lower corrosion rates, and water free products.

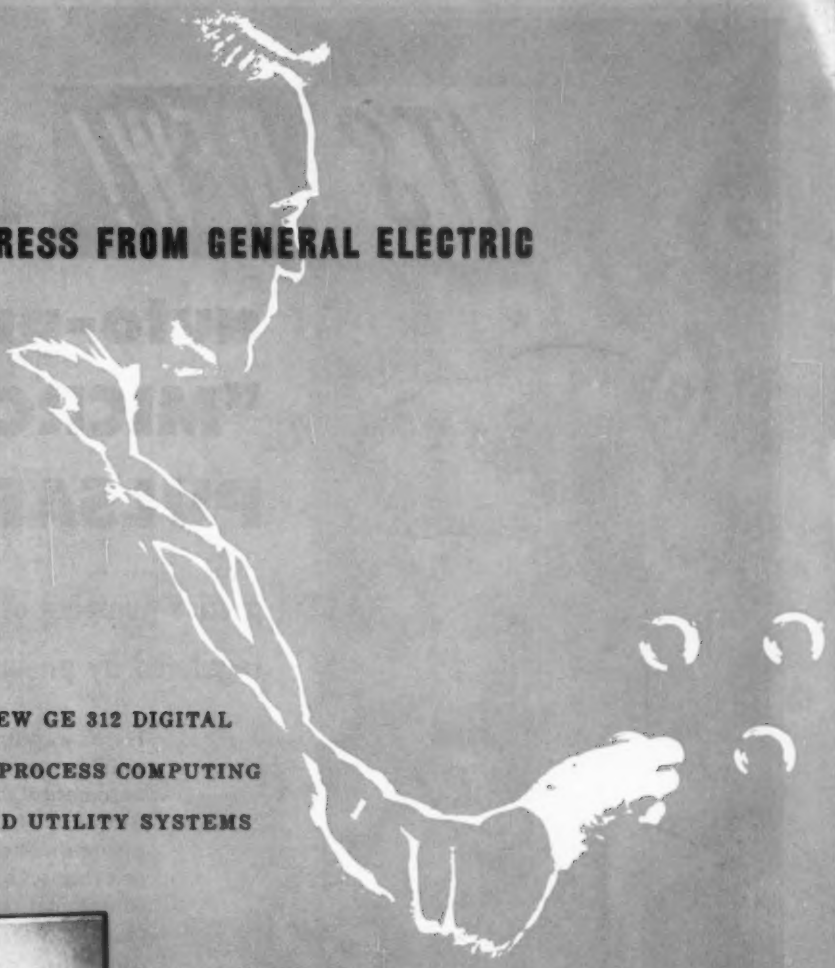
Products Handled — LPG, gasoline, naphtha, distillate, gas oil, aromatics.

Special Uses—Feed stocks, treated and water-washed products, finished products to storage.

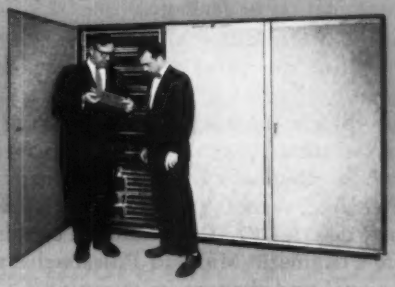
Description — Fram-Warner Lewis separator/filters offer a flexibility of design to meet a variety of process applications — Vertical single stage, horizontal single stage, horizontal two stage separator/filters with entrained water removal efficiencies of 90 to 100% and filtration efficiency down to 5 microns particle size. Engineering design and pressure vessel fabrication facilities at Warner Lewis Tulsa plant are always available to handle special problems to customer specifications. Let proven experience in the field in countless process applications help you.

For Further Information — Write Process Section Warner Lewis Company, Division of Fram Corporation, Box 3096, Tulsa, Oklahoma, for Process Manual on water separators/filters. Warner Lewis representatives are located throughout the United States and Canada and they will be glad to contact plant processing and operating personnel.

COMPUTER PROGRESS FROM GENERAL ELECTRIC



ANNOUNCING THE FLEXIBLE NEW GE 312 DIGITAL CONTROL COMPUTER FOR ON-LINE PROCESS COMPUTING APPLICATION IN INDUSTRIAL AND UTILITY SYSTEMS



GE 312 DIGITAL CONTROL COMPUTER

Newest member of a distinguished family of General Electric computers, the GE 312 *transistorized* DIGITAL CONTROL COMPUTER has been especially designed for process control, data logging, and data processing requirements imposed by industrial and utility operation.

• "Big Machine" features—moderate in cost • Expansible memory capacity • Easily programmed • Advanced programming aids available • Rugged construction for industrial application • Off-line operation as a general purpose computer

Request brochure CPB-36. For more information on computers, computing control and automation, contact your nearest General Electric Apparatus Sales Division Office, or write to: Computer Department, Room 3300A General Electric Company • Deer Valley Park • Phoenix, Arizona.

Progress Is Our Most Important Product

GENERAL ELECTRIC

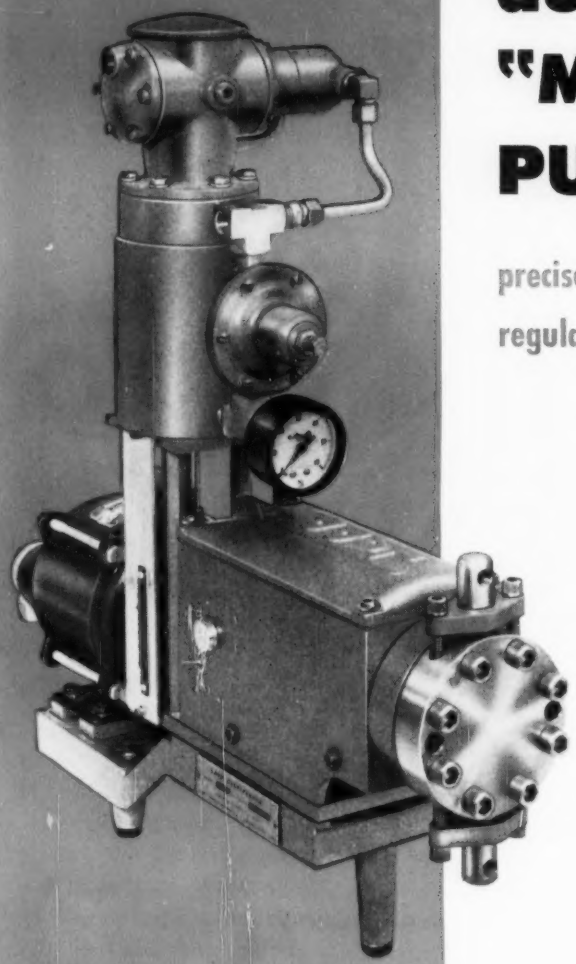
FOR FIGURES IN A HURRY—FIGURE ON A GE COMPUTER

CPA-16 [illegible]

IT'S NEW! Lapp

auto-pneumatic "MICROFLO" PULSAFEEDER

precise pumping at micro-flow rates
regulated by pneumatic control instruments



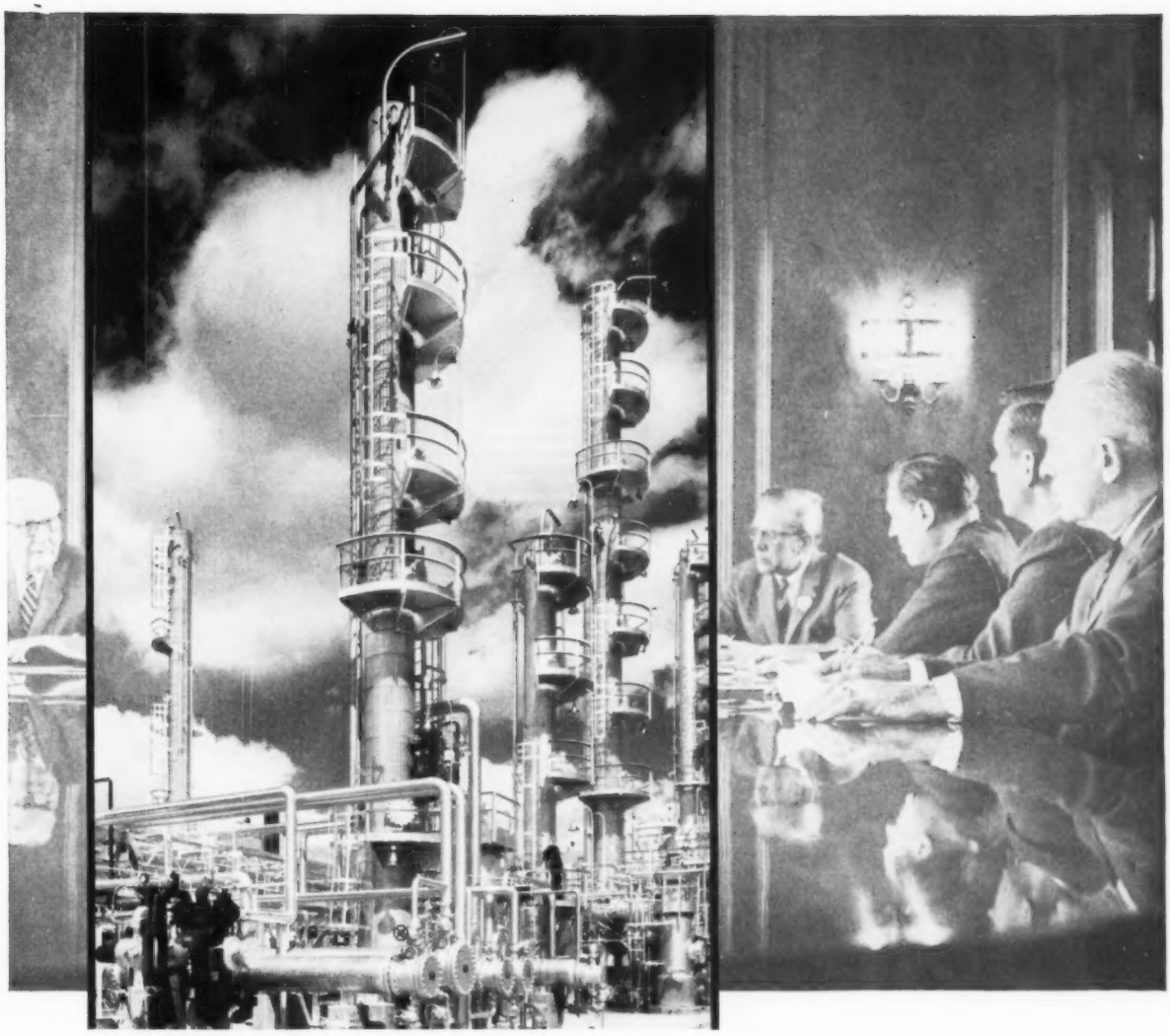
Here's a controlled-volume metering pump that will vary its microflow rate of output automatically to a changing process condition. Auto-Pneumatic Microflo Pulsafeeder is a piston-diaphragm pump with no stuffing box or other seal—it handles fluids without contamination or leakage.

Output of a standard Microflo is governed by controlling the travel of its piston. This is done manually through a micrometer. In the Auto-Pneumatic model, an air cylinder performs this operation. As a change in a process condition occurs, a pneumatic control instrument senses the change, records it and sends an air pressure signal descriptive of the changed condition. Auto-Pneumatic Microflo Pulsafeeder reads this air signal and changes its pumping rate accordingly.

Four models are available with flow rangeability of 10 to 1 and a flow range from 585 ML per hour maximum up to 1.2 gph maximum. Reagent head assembly is made from Carpenter No. 20 Stainless, Diaphragm is Kel-F and valves are Hastelloy C. Other materials are available on special order.

Lapp

WRITE FOR BULLETIN 500-A containing complete description and specifications on the new Auto-Pneumatic Microflo Pulsafeeder.
Lapp Insulator Co., Inc., Process Equipment Division, 3407 Poplar Street, Le Roy, New York.



Pritchard applies automatic data logging with, above all, GOOD FINANCIAL DESIGN

Socony's new 6000 bbl/day catalytic reforming unit at Casper, Wyoming might have been just another refinery addition–except for one vital difference. Along with the usual vessels and piping, J. F. Pritchard & Co., engineers and builders of the unit, provided a complete data logging and scanning system to monitor processes. This centralized automatic system supplements manual supervision and contributes to more efficient operation. The end result is lower operating costs and more profitable refinery operation.

The construction of this ultra-modern refining unit is an example of how Pritchard looks beyond the obvious to engineer and build plants with good financial design – the "extra" that gives Pritchard clients maximum return on capital.

Pritchard's experience in petroleum ranges from the design, engineering and construction of individual processing units to complete refineries. Pritchard also serves the oil field processing industry with facilities for operations such as sulphur removal and recovery, natural gas dehydration and pressure maintenance. If you are considering new construction in these fields, ask Pritchard to show you how good financial design can work for you.

PROFITABLE FACILITIES THROUGH GOOD FINANCIAL DESIGN

J.F. Pritchard & Co.

ENGINEERS • CONSTRUCTORS

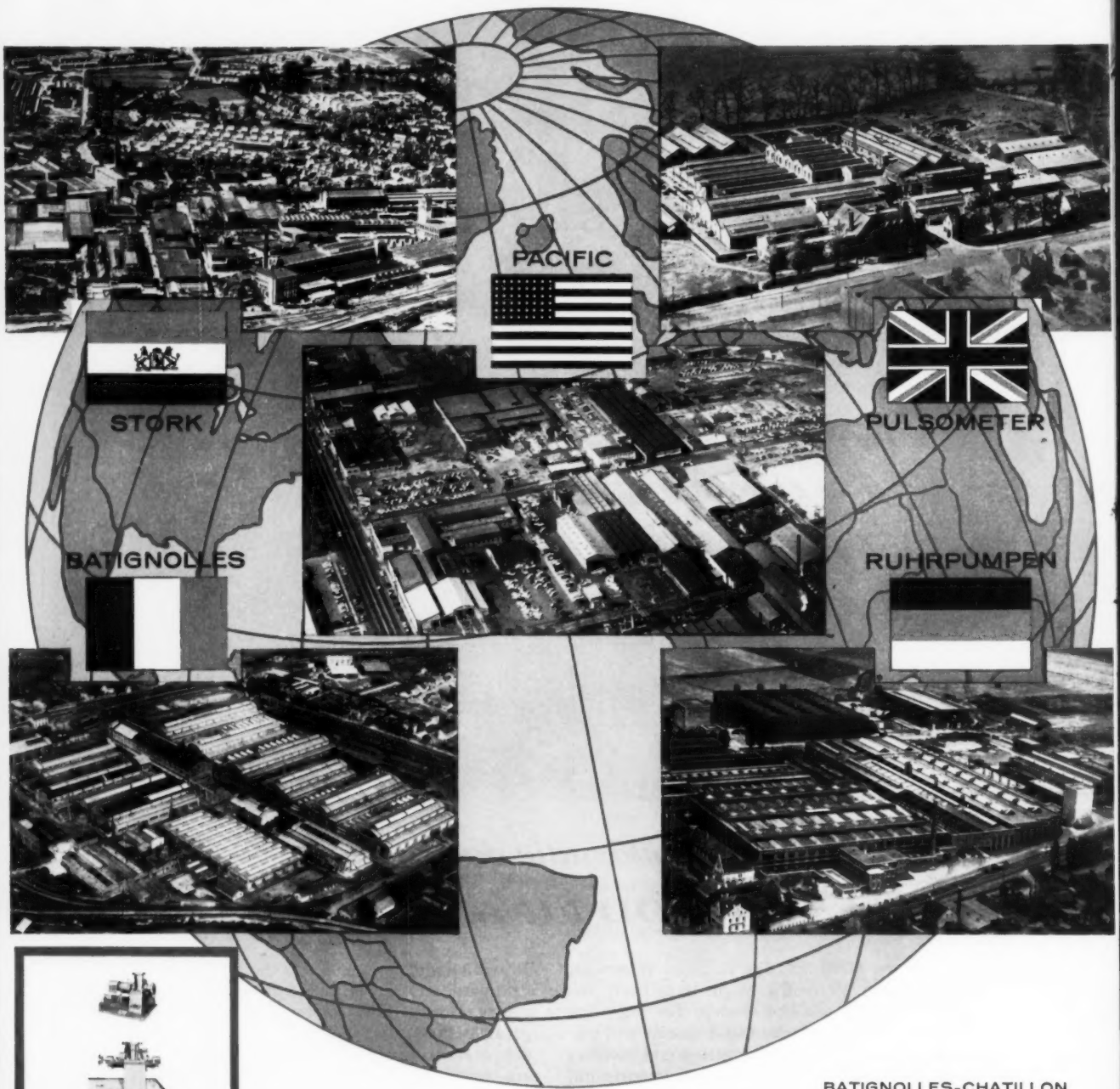
Dept. 406, 4625 Roanoke Parkway, Kansas City 12, Mo.

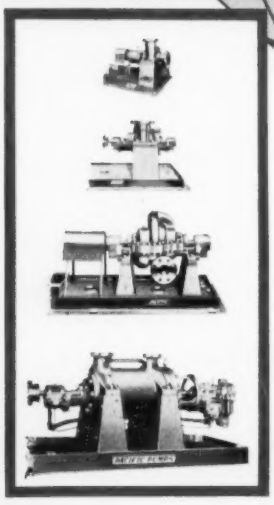
OFFICES IN CHICAGO, HOUSTON, PITTSBURGH, NEW YORK

SERVING THE GAS, POWER, PETROLEUM AND CHEMICAL INDUSTRIES

For more data on advertised products, use Readers' Service Cards, last page.

Pacific Pumps offers WORLD-WIDE Manufacturing





Pacific pumps designed specifically for use in petroleum refineries, petrochemical and other processing plants throughout the world are universally recognized for superior performance . . . long service life . . . trouble-free operation . . . low maintenance costs. Whether these pumps are built in Pacific's American plant or by one of the carefully selected foreign manufacturers – identical integrity of design, engineering, workmanship, materials and service is assured. Through these world-wide facilities, centrifugal pumps of Pacific design may be purchased in Sterling, Francs, Guilders, Marks, Dollars or other foreign currencies. We encourage your inquiries.

BATIGNOLLES-CHATILLON
5, Rue de Monttessuy, Paris (7e), France

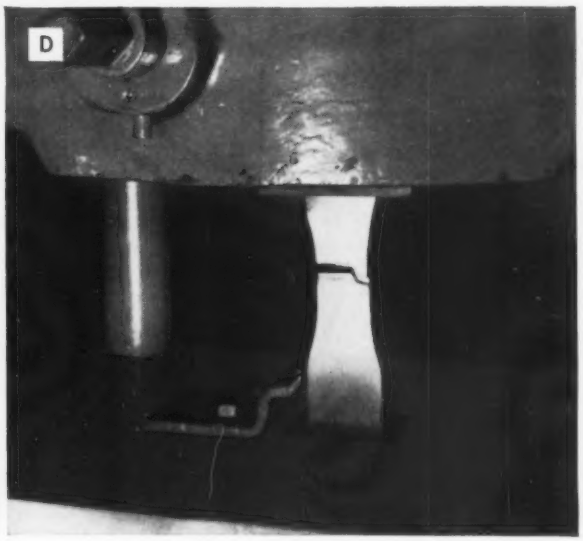
KONINKLIJKE MACHINEFABRIEK GEBR. STORK & CO.
N. V. (V.M.F.) Hengelo (o), The Netherlands

THE PULSOMETER ENGINEERING COMPANY LTD.
Nine Elms Iron Works, Reading, England

RUHRPUMPEN G.m.b.H.
Division of RUHRSTAL A.G.
Stockumer Strasse 10-Witten-Annen, Germany

DRESSER A.G.
MUHLEBACHSTRASSE 43
ZURICH, SWITZERLAND

PACIFIC PUMPS INC.
A DIVISION OF DRESSER INDUSTRIES, INC.
HUNTINGTON PARK, CALIFORNIA, U. S. A.



Our testing team works for you

Your requirements come first with our testing team. Working directly under our chief engineer, they check and double-check the fabrication work of our production crews. Your own men couldn't do a more faithful job. Come and see for yourself. Or write for Bulletins HE and CI.

A **For a close fit**—Incoming tubes are always miked for exact size. Matching tube sheets are then reamed for a close fit that contributes to heat exchanger quality.

B **Tailored to size**—Quality dictates precise tube hole diameter. Constant micrometer checking tells our inspector that tube sheets are exactly right to meet your specs.

C **In the dark**—but not for long. Our own darkroom permits immediate developing of X-ray films...gives our inspector a fast check of weld structure and soundness.

D **Reply requested**—Our inspectors get many prompt reports from our own testing lab. Here's a tensile test on our own machine. It helps speed testing and inspection.

Downingtown Iron Works, Inc.

151 Wallace Ave., Downingtown, Pennsylvania

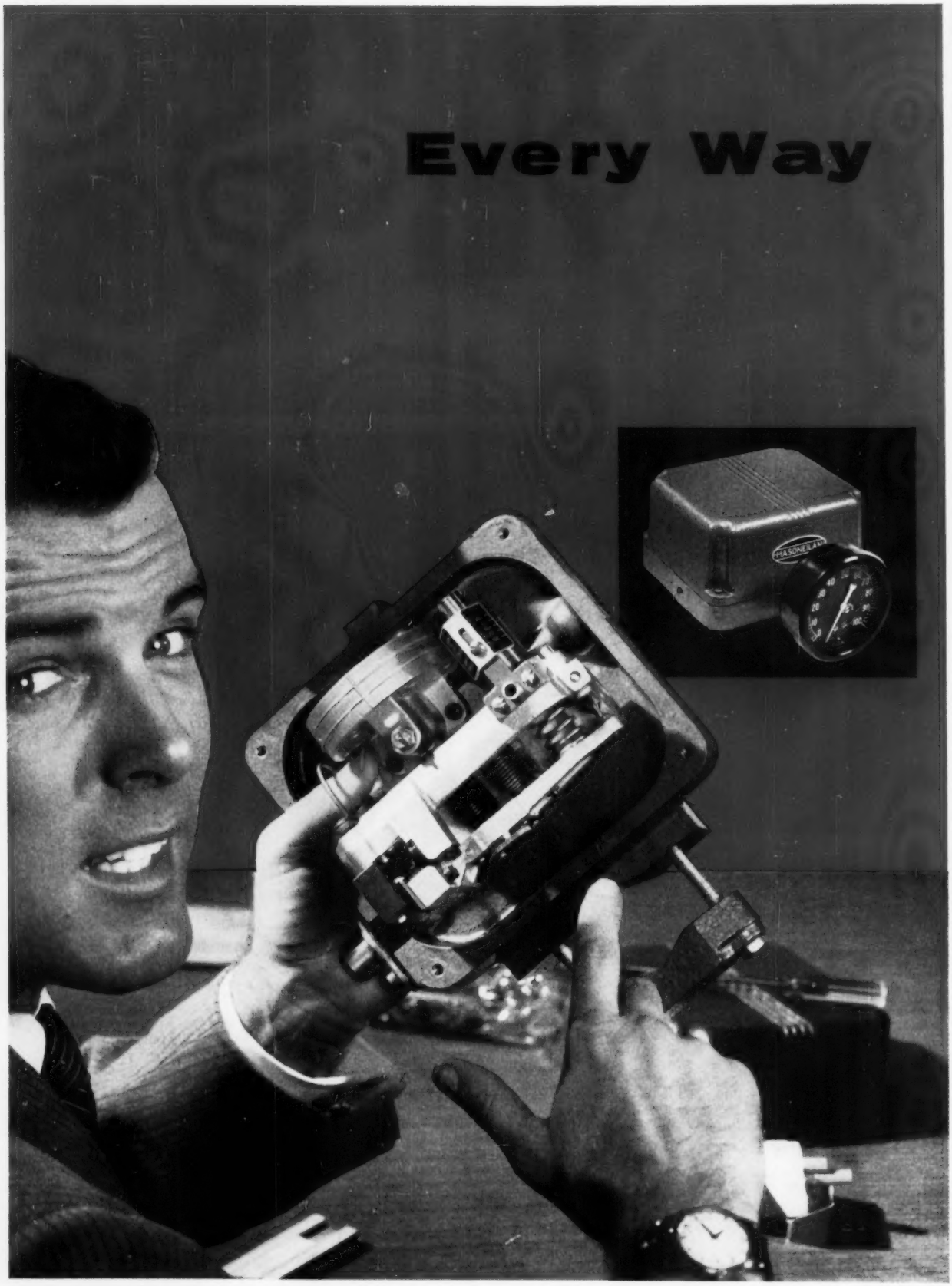
division of **PRESSED STEEL TANK COMPANY** Milwaukee

Branch offices in principal cities

HEAT EXCHANGERS—STEEL AND ALLOY PLATE FABRICATION
CONTAINERS AND PRESSURE VESSELS FOR GASES, LIQUIDS AND SOLIDS

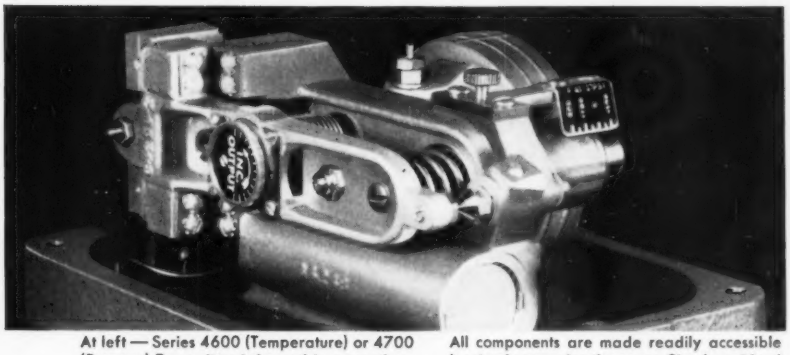
DOWNINGTOWN IRON WORKS INC. Hackney

For more data on advertised products, use Readers' Service Cards, last page.


Every Way

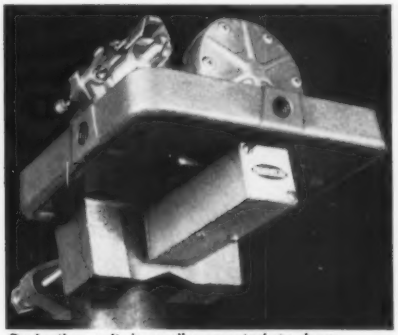
You Look At It!

New Masoneilan Transmitter Offers High Performance, Ease of Installation and Maintenance



At left — Series 4600 (Temperature) or 4700 (Pressure) Transmitter is housed in a weatherproof aluminum case, with blue Hammertone finish. Weighs only about 8 lbs.

All components are made readily accessible by simply removing the cover. Simple, unitized construction makes everything compact, yet easy to adjust and maintain.



Derivative unit is easily mounted to base plate without tubing or fittings. Integral mounting of receiver gauge on front edge of base plate is also optional.

One look at the Masoneilan Temperature or Pressure Transmitter will show you its simple, compact and rugged design. All of the elements have been neatly tailored into a 7″ x 6″ area, only 3¾″ high; yet all adjustments are visible and easily accessible — performance is accurate and dependable.

Unitized construction is a major advancement. All sub-assemblies can be easily changed or removed individually, without disturbing the beam assembly. And the Derivative unit and Receiver Gauge may be integrally mounted on the base plate, requiring no tubing or fittings.

The new Masoneilan Transmitter is easily and quickly mounted to a pipe or flat surface — in any position found convenient, because the balanced beam eliminates zero shift.

This is your kind of instrument — built for dependable operation and easy maintenance! Send for new Bulletin which provides complete data and specifications.

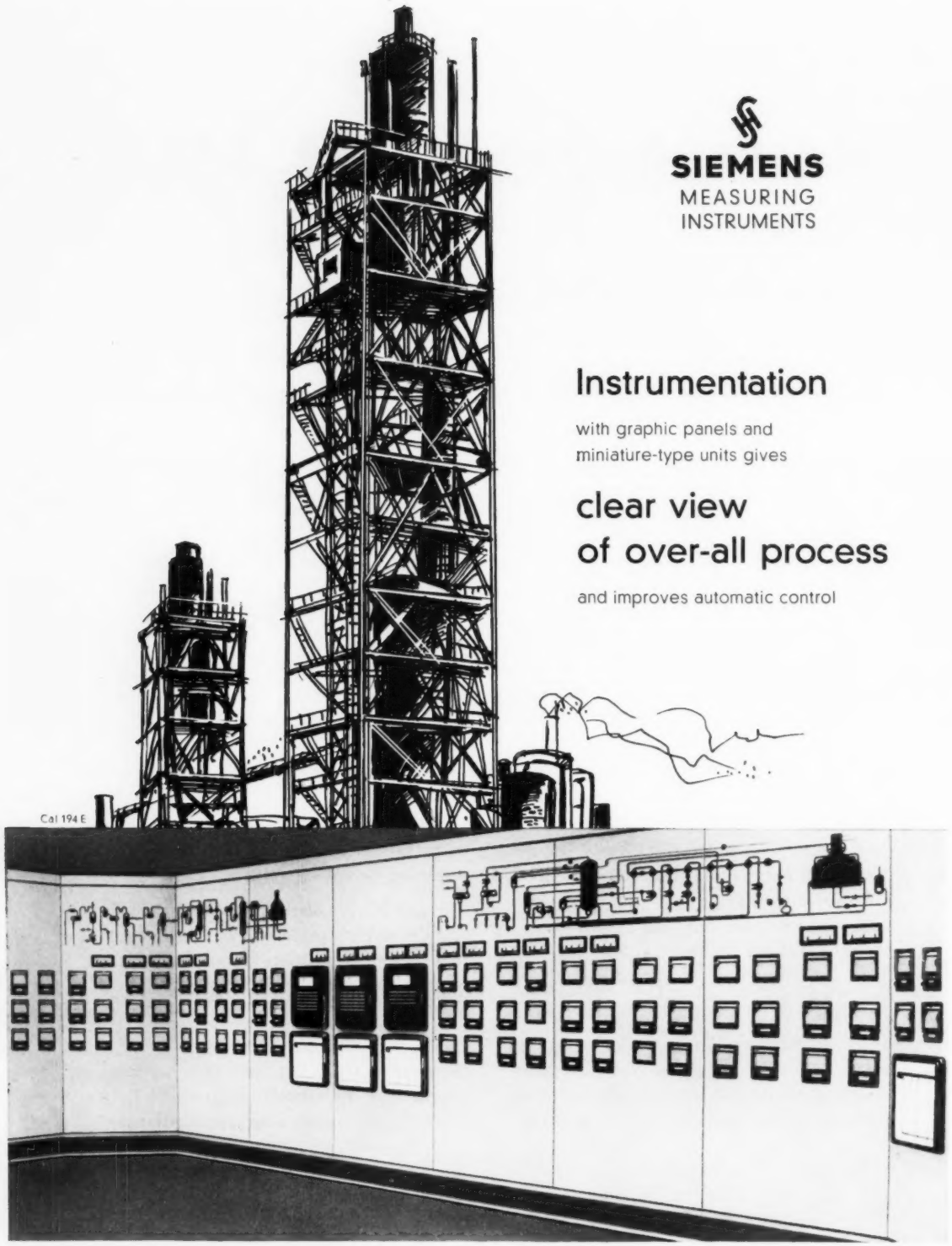
MASON-NEILAN

A Division of Worthington Corporation

51 NAHATAN STREET, NORWOOD, MASSACHUSETTS

District offices or Distributors in principal cities in U.S.
In Canada: Mason-Neilan, Division of Worthington (Canada), Ltd.

MN7-32



SIEMENS
MEASURING
INSTRUMENTS

Instrumentation

with graphic panels and
miniature-type units gives

clear view of over-all process

and improves automatic control

SIEMENS & HALSKE AKTIENGESELLSCHAFT
BERLIN · MÜNCHEN

AGENTS
SIEMENS NEW YORK INC.
350, FIFTH AVENUE · NEW YORK 1, N.Y. · TELEPHONE: LONGACRE 4-7674

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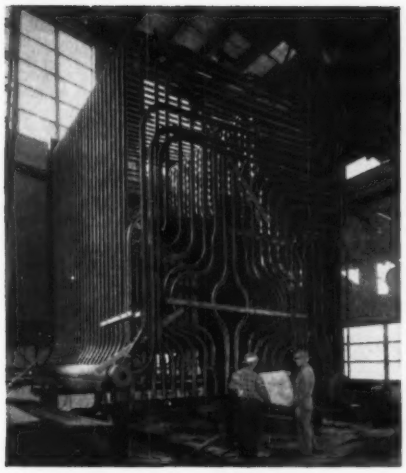
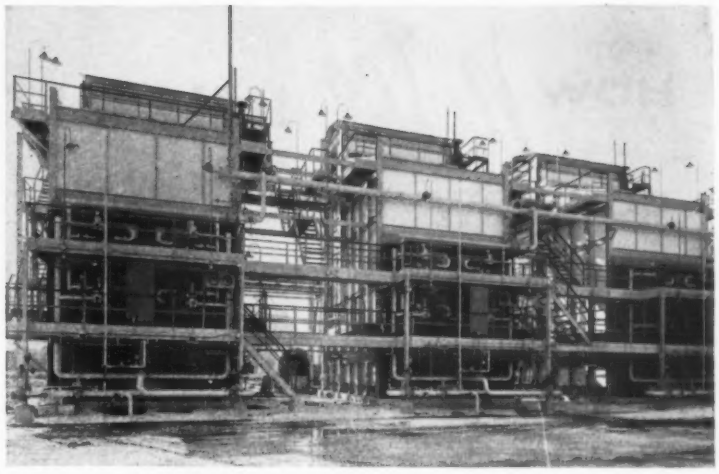




AT LEFT: Installing a 60,000 lbs/hr unit in a brewery

ABOVE: A battery of 125,000 lbs/hr units in a chemical plant

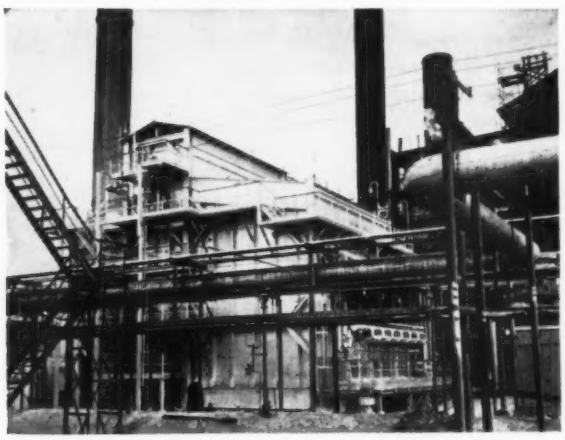
CUSTOM *Steam* GENERATORS

Vogt engineering advances can save you money if you have a steam generating problem. Custom-built installations shown, are engineered to assure efficient, dependable steam generation for power, process and heating. Our engineering staff is available to give effective help in the solution of steam generating problems peculiar to a wide variety of operating conditions. Address Dept. 24A-BPR.

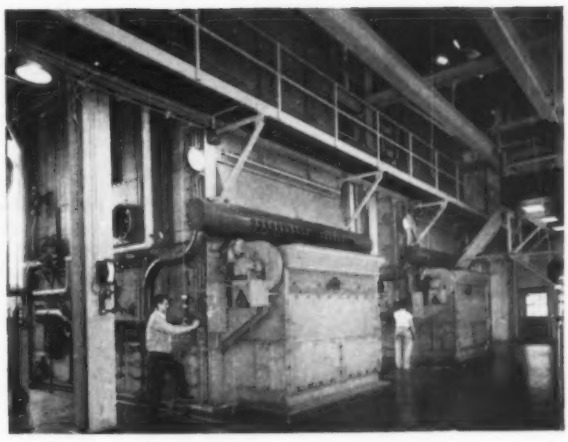
by Vogt

HENRY VOGT MACHINE CO.
LOUISVILLE, KENTUCKY

SALES OFFICES: New York, Chicago, Cleveland, Dallas, Camden, N. J., St. Louis, Charleston, W. Va., Cincinnati



This 400,000 lbs/hr unit is installed in a leading petroleum refinery



Three 40,000 lbs/hr units serve a medical center

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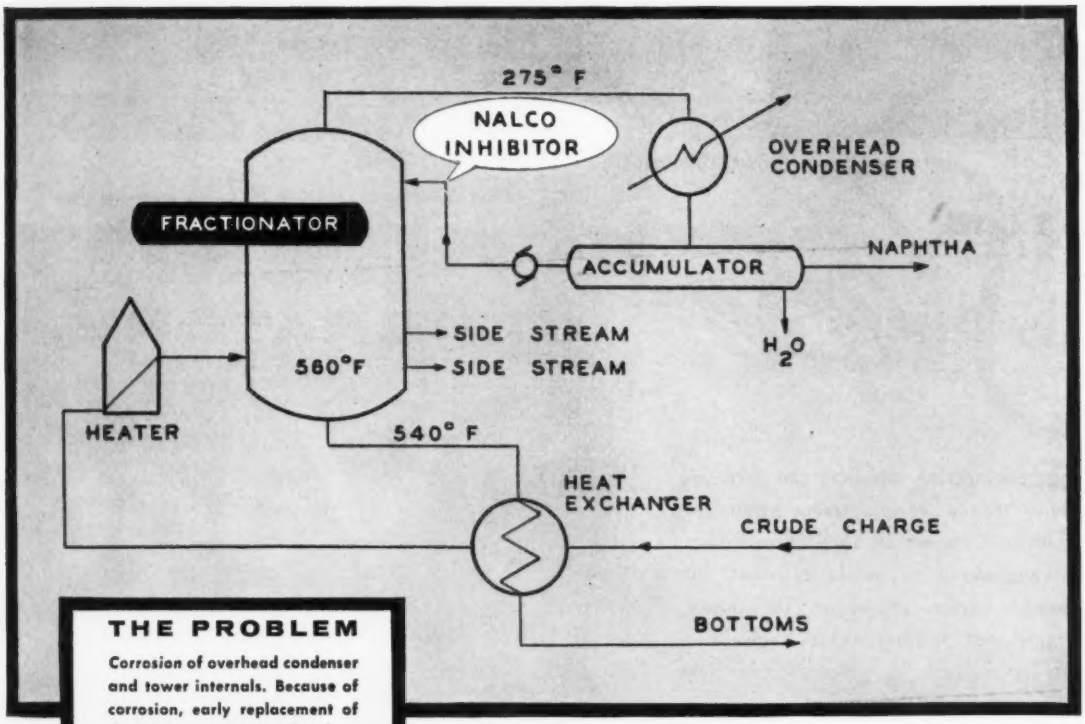
HOW *Nalco* INHIBITORS CUT DOWNTIME 74%...AND SAVED THIS FRACTIONATING TOWER



THE PROBLEM

Corrosion of overhead condenser and tower internals. Because of corrosion, early replacement of the tower was contemplated.

THE TREATMENT

Nalco Corrosion and Fouling Inhibitor applied into overhead reflux.

THE RESULT

In this case only one point of application protected both fractionator and overhead equipment. Iron in accumulator water brought below 0.5 ppm as compared to previous 100-150 ppm. Corrosion and plugging stopped, tower saved, and downtime for cleaning reduced by 74%.

EFFECTIVE Nalco corrosion control is very low-cost protection. For example, this refinery not only avoided the cost of a new tower, but cleaner tower internals actually resulted in better fractionation and higher quality products. If you would like further facts on Nalco Corrosion and Fouling Inhibitors, ask your Nalco Representative or write direct.

NATIONAL ALUMINATE CORPORATION
6259 West 66th Place • Chicago 38, Illinois
Telephone: POrtsmouth 7-7240
CANADA: Alchem Limited, Burlington, Ontario
NORTHWESTERN UNITED STATES, HAWAII and ALASKA
The Flox Company, Inc., Minneapolis 3, Minnesota
ITALY: Nalco Italiana, S.p.A.
WEST GERMANY: Deutsche Nalco-Chemie GmbH
SPAIN: Nalco Espanola, S.A.

THE *Nalco*® SYSTEM ...SERVING INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE

Nalco CHEMICALS

M·A·N

The following are some of the products we design and manufacture:

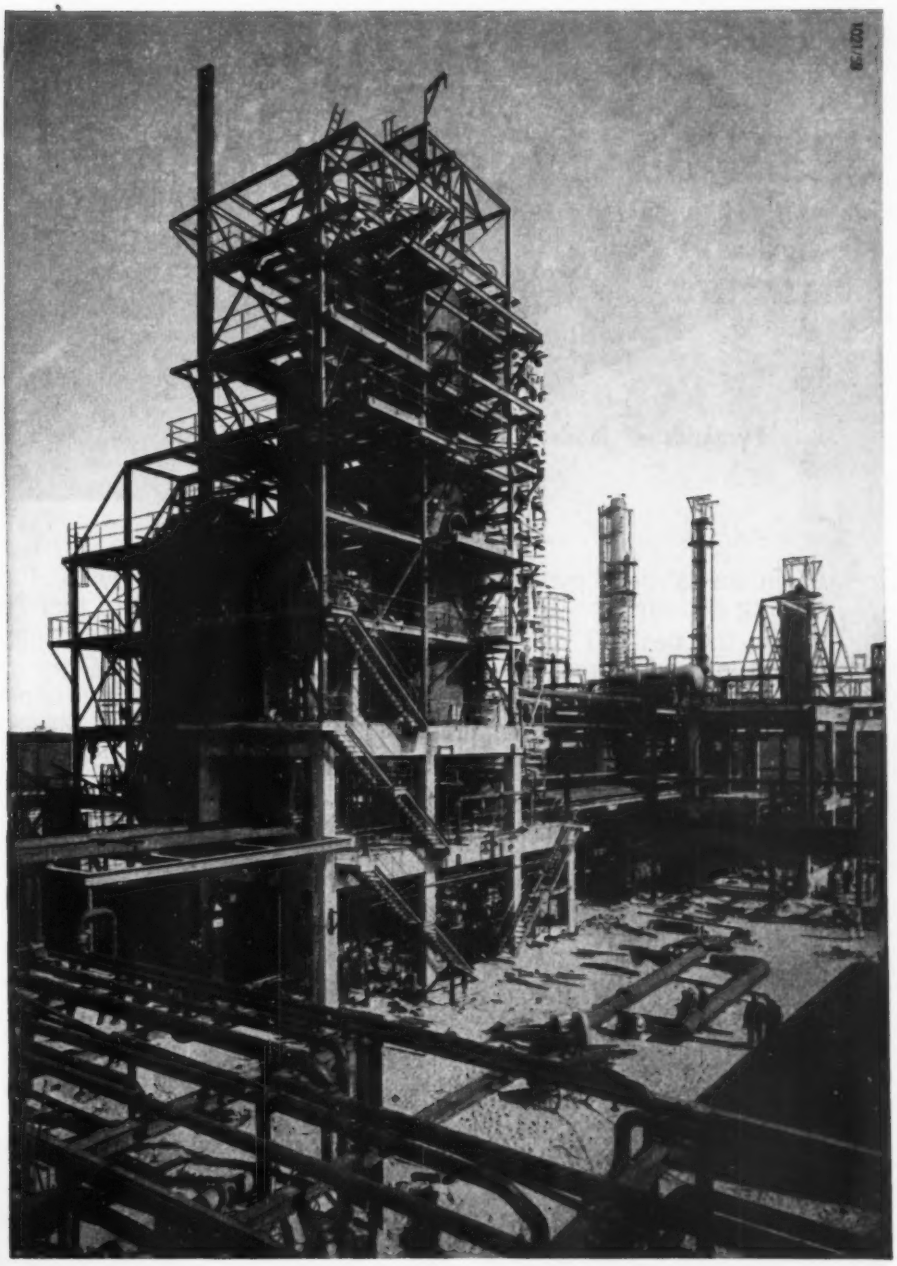
STEAM BOILERS

STEAM POWER STATIONS

TURBINES

DIESEL ENGINES

GAS ENGINES

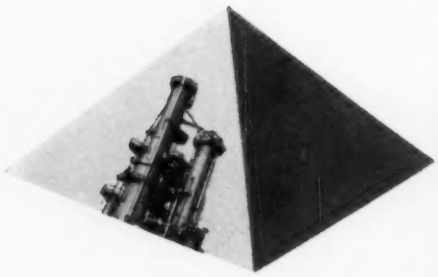


Responsible for process and engineering were: N. V. de Bataafsche Petroleum Mij., The Hague and Lummus Nederland N. V., The Hague. Responsible for purchasing was: Edeleanu GmbH, Frankfurt.

We recently supplied and installed all apparatuses and structural steelwork required for the

CAT CRACKER AND GAS RECOVERY PLANT
DEUTSCHE SHELL AG
HOHE SCHAAR REFINERY, HAMBURG

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) · REPRESENTATIVES IN ALL COUNTRIES



Pyramids of Modern Times

Petroleum and Petro-Chemical plants built by JGC

As in the ancient pyramids, superior technical know-how and the finest in engineering performance are today still the inseparable factors that construct to endure.

During the past 30 years the Japan Gasoline Company has built some of the best petroleum and petro-chemical plants in Japan, providing a highly diversified service in building... from the designing to the construction... all in one favorable contract.

An expert staff offers competent planning for every step of the way... with the assurance to meet the demands of the most exacting customer.

JGC

ENGINEERS & CONSTRUCTORS

JAPAN GASOLINE CO., LTD.

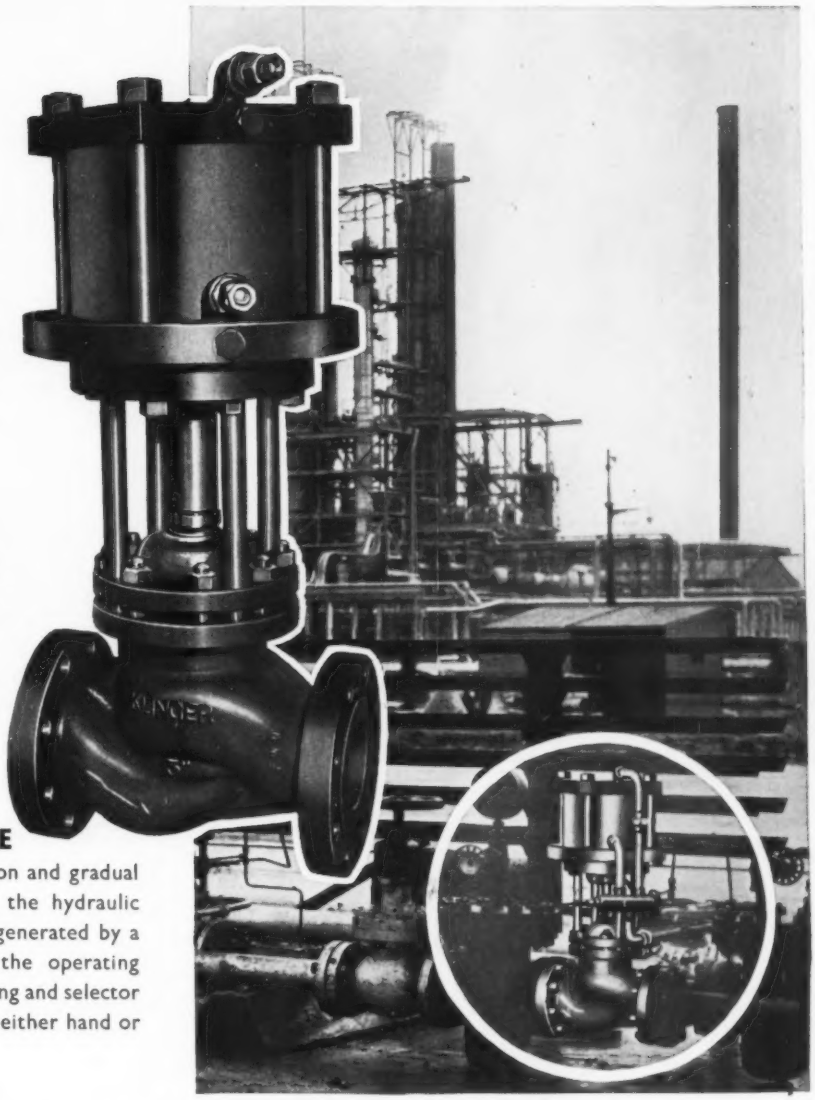
New Otemachi Bldg., 4-2, Otemachi, Chiyoda-ku.
Tokyo, Japan. Cables: "ANTIKNOCK TOKYO"

For more data on advertised products, use Readers' Service Cards, last page.

Klingermatic

REMOTE CONTROL PISTON VALVES

AIR & HYDRAULIC OPERATED



The Klinger Piston Valve readily lends itself to remote control by air and hydraulic operation, and as such Klingermatic Air or Hydraulically Operated Valves are ideally suited for remote control of filling lines, emergency valves, drop-out valves, etc.

AIR-OPERATED VALVE gives a rapid opening and closing. Control of the valve is provided by a small hand-operated valve or push button, which can be situated 100 ft. or more away. A number of valves can be operated simultaneously by the same control, or a single valve can be controlled from more than one station.

HYDRAULIC-OPERATED VALVE gives positive control in any position and gradual opening and closing. Control of the hydraulic valve is provided by oil pressure, generated by a pump, which is transmitted to the operating cylinders through metering, reversing and selector valves. The selector valves can be either hand or electrically operated.

THE KLINGER CORPORATION OF AMERICA, 95 RIVER STREET, HOBOKEN, NEW JERSEY
Telephone: OLDFIELD 6-1300.

Manufacturing Licensees for Canada

JOSEPH ROBB & COMPANY LIMITED, 5575, COTE ST. PAUL ROAD, MONTREAL, 20, CANADA
Telephone : GLENVIEW 9151
Branches at: SYDNEY, HALIFAX, OTTAWA, TORONTO, HAMILTON, WINNIPEG, EDMONTON, VANCOUVER, QUEBEC CITY

RICHARD KLINGER LIMITED, KLINGERIT WORKS, SIDCUP, KENT, ENGLAND.

GA45/58/KM

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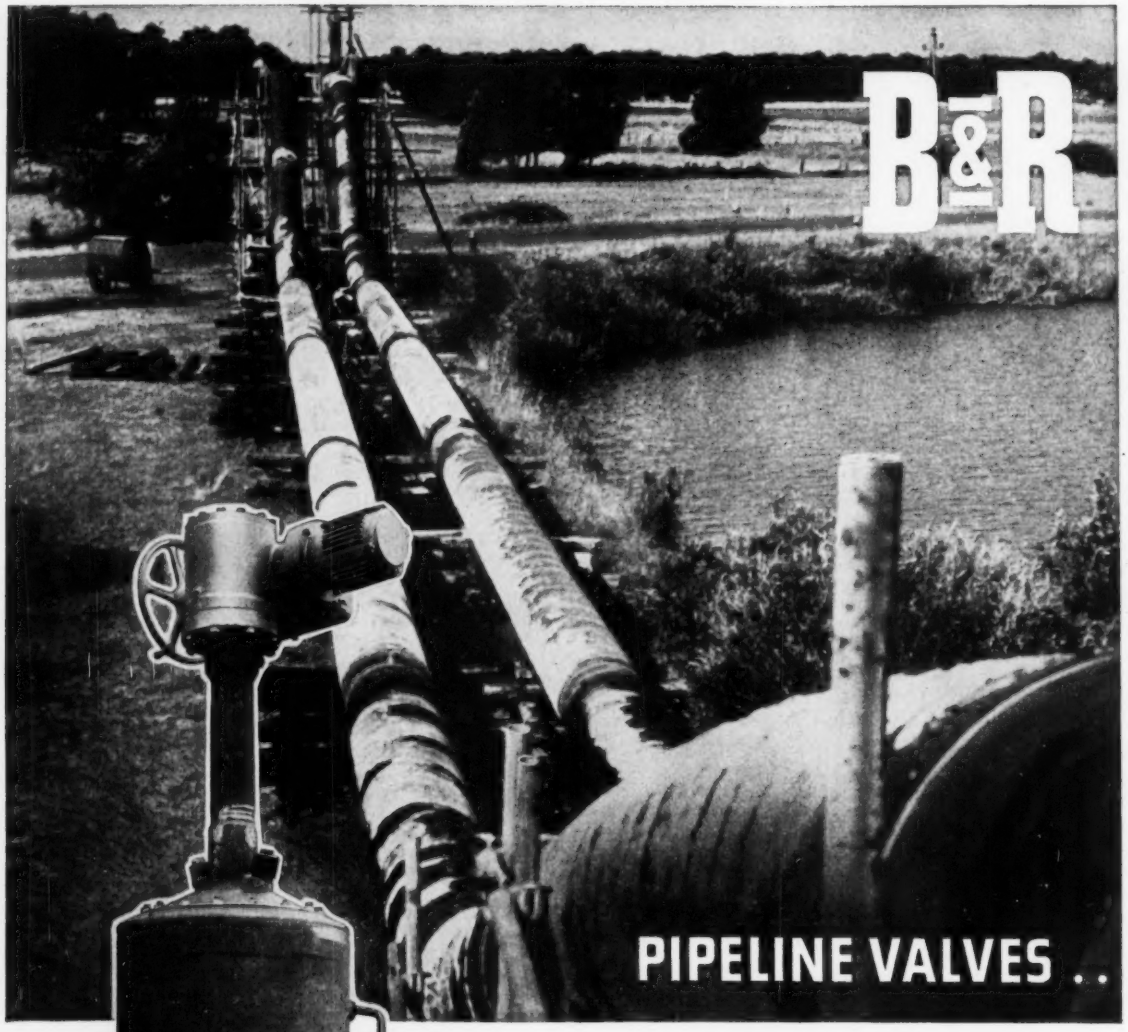


... produced by BOPP & REUTHER are in use in the 24" and 28" pipelines running from Wilhelmshaven to Cologne and from Rotterdam to Cologne. The biggest pipeline of the Arabian Peninsula will have 30" valves made by BOPP & REUTHER.

Please consult our pipeline engineers.

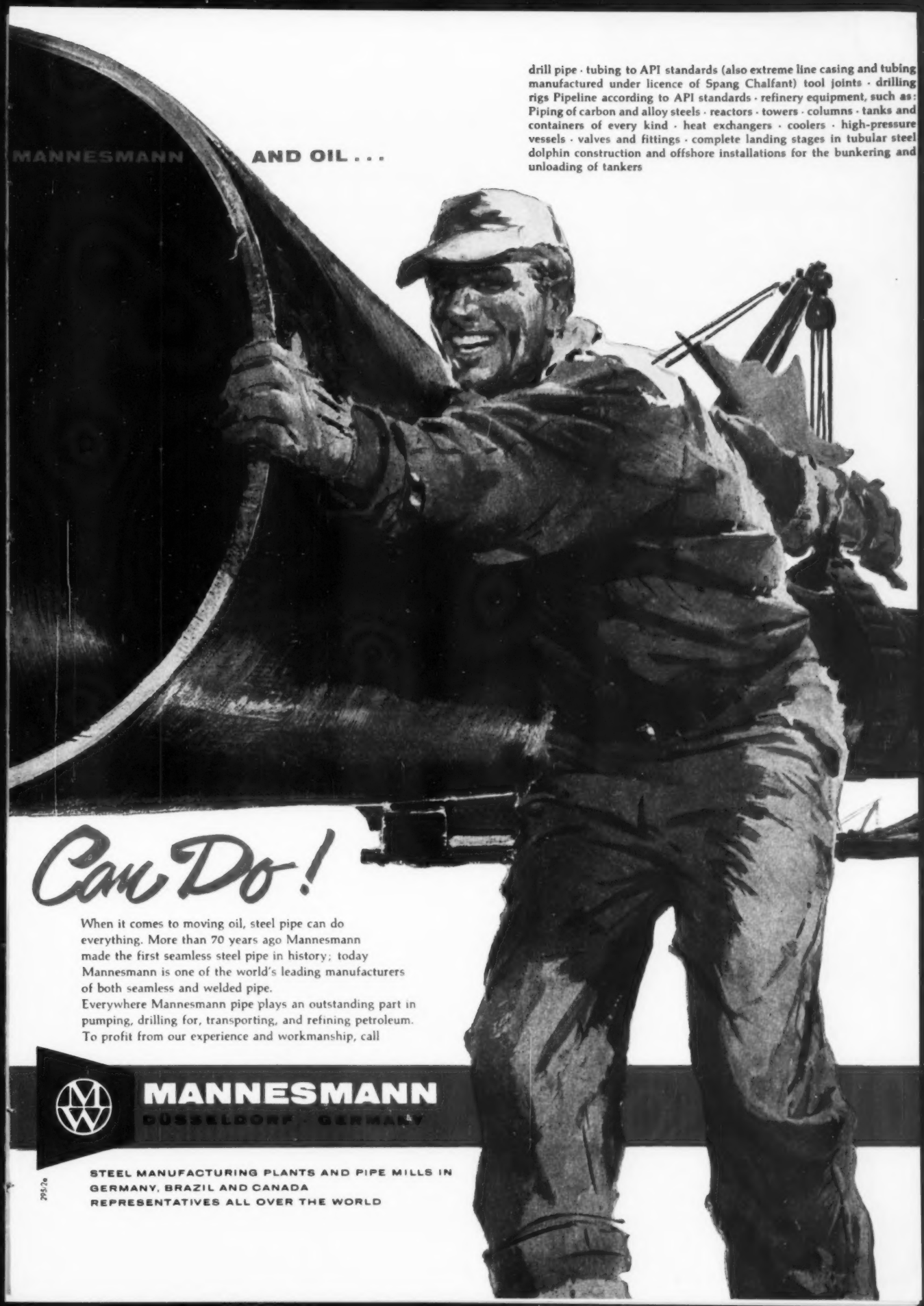
B&R GATE VALVES

for pipelines

BOPP & REUTHER GMBH MANNHEIM-WALDHOF

Oe 758 e

Western Germany


MANNESMANN AND OIL . . .
drill pipe · tubing to API standards (also extreme line casing and tubing manufactured under licence of Spang Chalfant) tool joints · drilling rigs Pipeline according to API standards · refinery equipment, such as: Piping of carbon and alloy steels · reactors · towers · columns · tanks and containers of every kind · heat exchangers · coolers · high-pressure vessels · valves and fittings · complete landing stages in tubular steel dolphin construction and offshore installations for the bunkering and unloading of tankers
Can Do!
When it comes to moving oil, steel pipe can do everything. More than 70 years ago Mannesmann made the first seamless steel pipe in history; today Mannesmann is one of the world's leading manufacturers of both seamless and welded pipe.
Everywhere Mannesmann pipe plays an outstanding part in pumping, drilling for, transporting, and refining petroleum.
To profit from our experience and workmanship, call
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STEEL MANUFACTURING PLANTS AND PIPE MILLS IN GERMANY, BRAZIL AND CANADA
REPRESENTATIVES ALL OVER THE WORLD
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AMSTERDAM

ARE SERVING THE OIL INDUSTRY

Saving of packing and transportation costs can also be realised by bulk transport. For bulk transport to the European refineries Ketjen has developed a special KETJEN POLYSIUS system, which has been installed in roadcars, railroad tankcars and steel containers. With this system the tankers can be discharged over a considerable distance, with minimum dust losses, at a rate of approx. 1 ton/min.

- **KETJENCAT M.S. Fluid Cracking Catalyst**
- **KETJENFORM M.S. Fluid Hydroforming Catalyst**
- **KETJENFINE Hydro-desulphurisation Catalyst**

• CK Platinum Reforming Catalyst

CYANAMID-KETJEN

In August 1958 Cyanamid-Ketjen N.V. started production of platinum reforming catalysts. These fully regenerative platinum catalysts give outstanding performance in upgrading low octane gasolines to high value motorgasoline components in catalytic reforming units.

"X" Catalysts

Improvements of the above mentioned catalysts are the objective of our research efforts and are carried out in our well-equipped laboratories and pilot plant facilities.

Sulphuric Acid / Liquid SO_2

NV CP

The sale of catalysts and other Ketjen products is being handled by
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63 Mauritskade, Amsterdam - Holland. P.O.B. 4038. Telephone 54322. Telex 12270. Telegrams: Chemicals

9E

what's the secret

why is Caposite so strong?

It's no secret why CAPOSITE insulation is so strong and stands up to such rough usage. These pipe sections and blocks are made wholly of Amosite asbestos and the long fibres of this particular kind of asbestos give CAPOSITE its strength and resilience as well as its high insulating value. This exceptional strength leads to many other features besides long life; it means that larger sizes of pipe sections and blocks are possible, making application easier and faster. Less care is needed in handling the material. Unlike other moulded insulation, CAPOSITE, because of its strength, can be shipped to refineries anywhere in the world *in cardboard cartons*, showing big savings in freight and storage costs.

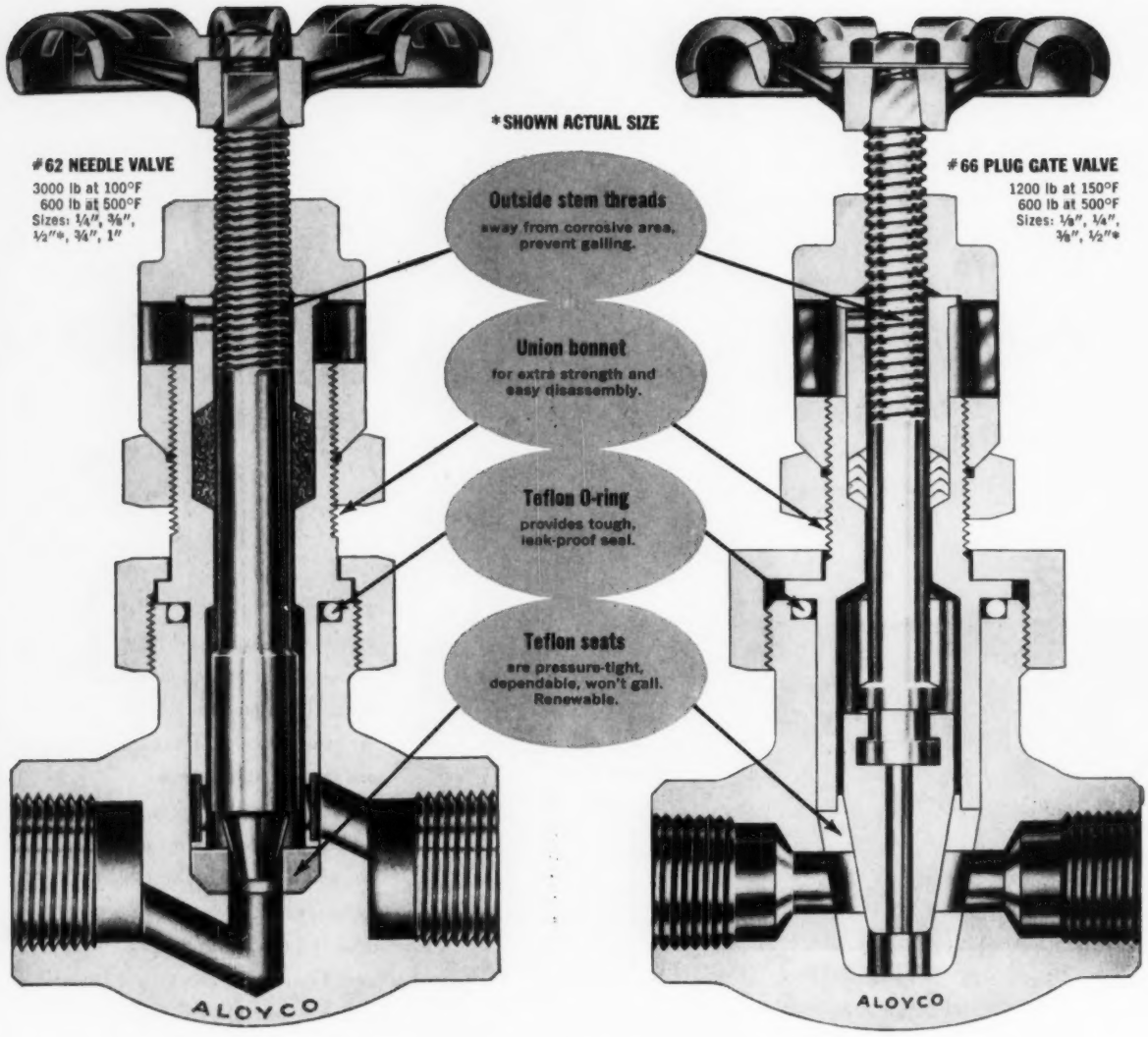
CAPOSITE Regd.

ASBESTOS INSULATION

THE CAPE ASBESTOS COMPANY LIMITED, 114 & 116 PARK STREET, LONDON W1 Tel: Grosvenor 6022 Cables: Incorrupt London

Enquiries in Canada to: Cape Asbestos (Canada) Limited, 200 Bloor Street East, Toronto, Ontario
U.S.A.: North American Asbestos Corporation, Board of Trade Building, Chicago 4, Illinois

TA 10642



radically different ALOYCO Stainless Steel Valves eliminate leakage and galling common to ordinary fine control valves

Introduced eight years ago, these two small Aloyco valves have proved themselves in many types of severe corrosive service as well as handling hard-to-hold fluids and high-pressure gases.

The No. 62 Needle Valve (left) is particularly suitable for sensitive control of flow . . . as in metering or sampling for process plant, laboratory or pilot plant use.

The No. 66 Gate Valve has a vented, full-floating plug disc, which exerts no twisting action on the removable Teflon seat in closing. It is ideal for instrument lines, in small lines handling viscous liquids, or where a low pressure drop is important.

For more facts write to Alloy Steel Products Company, 1303 West Elizabeth Avenue, Linden, New Jersey... the one manufacturer specializing in Stainless Steel Valves exclusively.

9.4

ALLOY STEEL PRODUCTS COMPANY LINDEN, N. J.

Boston · New York · Wilmington · Atlanta · Buffalo · Pittsburgh · Chicago · St. Louis · San Francisco · Los Angeles

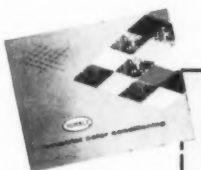
For more data on advertised products, use Readers' Service Cards, last page.

Paint in COLOR . . . . . for bonus benefits

Color adds to necessary protective painting these important *bonus benefits* • increased worker efficiency • a safer plant • better employee morale • a more pleasing appearance. And you can paint in color at little cost beyond that of routine maintenance painting.

Humble can supply the technical assistance and the color-conditioning paints necessary to put all the power of color to work for you. Without cost or obligation, one of Humble's trained engineers will make a thorough study of your plant and recommend a complete painting program.

HUMBLE



FREE BOOK tells you *how* to plan a color program for your industrial plant, refinery or tank farm. This colorful, illustrated book contains:

- **Basic principles of color conditioning**
- **The Safety Color Code**
- **Color identification of piping systems**
- **And other practical information on the use of color in industry.**

MAIL THIS COUPON . . . . .

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Please send me a copy of "Industrial Color Conditioning."

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if pollution is your problem . . .

Chemico venturi gas scrubbers have proved highly successful in solving air pollution problems in a wide variety of industrial applications. More than 400 venturi units have already been installed to clean up dust, fume and mist problems in the iron and steel, chemical, petroleum, metals, minerals, fertilizer and paper industries. Chemico's venturi scrubbers combine simplicity of design with very high efficiency—up to 99.95% in some applications.

Chemico Bulletin M104, illustrated here, gives a complete description of how venturi scrubbers operate and where they are now in use. Address your request for this brochure to Department GSR at the address below.

CHEMICO

CHEMICAL CONSTRUCTION CORPORATION
525 West 43rd Street, New York 36, New York

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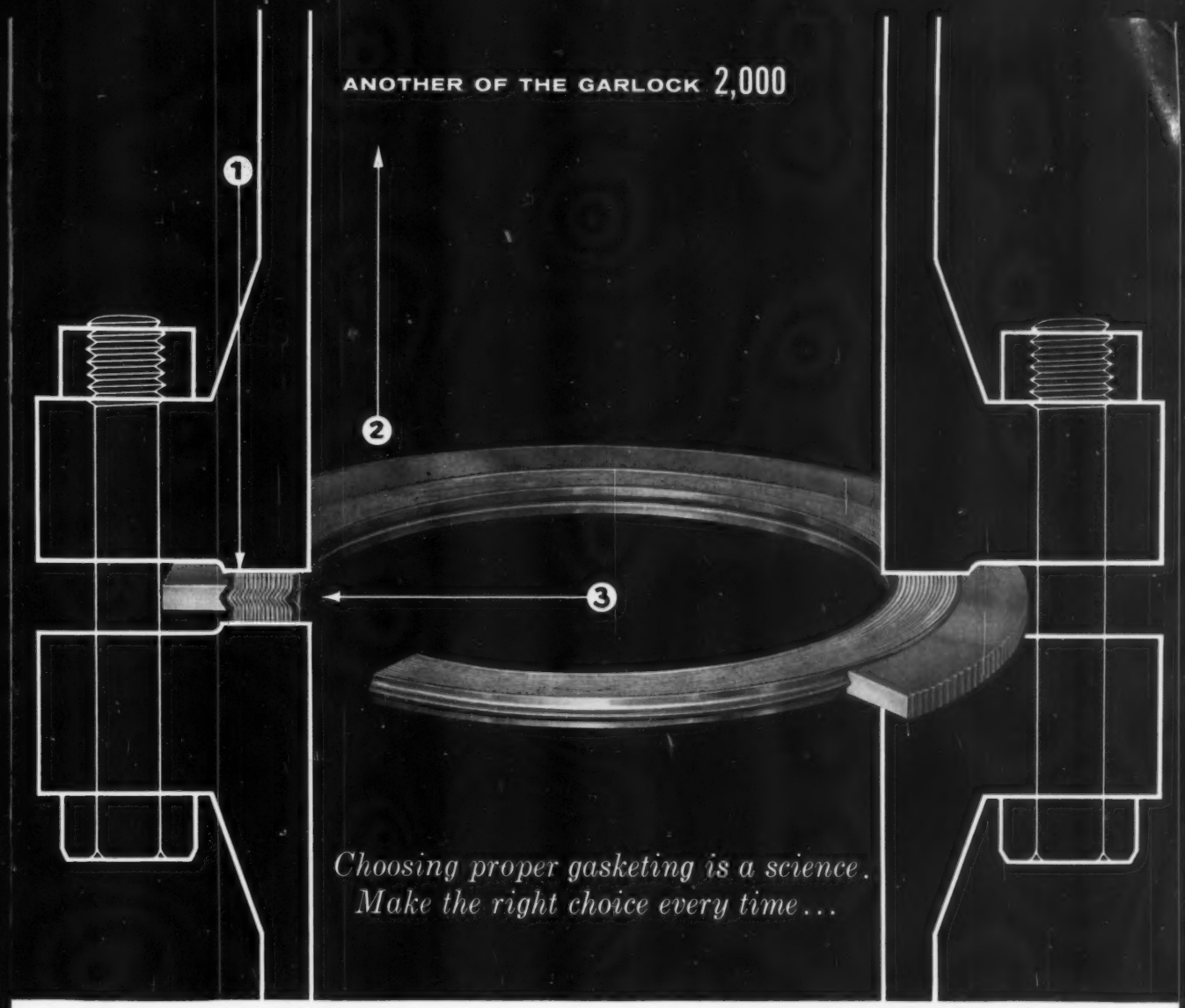


SELECT GARLOCK GUARDIAN* GASKETS FOR EXTREME TEMPERATURES, PRESSURES

Expertly-engineered GUARDIAN gaskets provide the necessary resilience and flow required by:

1. **BOLT LOAD** . . . seating force needed to make the gasket flow into the flange face imperfections to maintain tight seal against internal pressure
2. **HYDROSTATIC END FORCE** . . . pressure applied to a gasketed assembly by confined gases or liquids which tends to separate the flanges
3. **INTERNAL PRESSURE** . . . acts on the portion of a gasket exposed to the pressure side of a joint and tends to by-pass the gasket

Garlock GUARDIAN Gaskets are constructed of spiral-wound strips of V-shaped metal alternated with layers of asbestos paper or TEFLON†. By increasing or decreasing the number of layers the compressibility of GUARDIAN gaskets can be changed to meet different pressure and bolt loads—in no other type gasket can this be done!

Where operating conditions are unusually severe, apply TEFLON Garlock GUARDIAN gaskets to assure safe, positive sealing against practically all chemicals at temperatures from −300°F. to +450°F. For service against oils, steam, gases, liquids, at temperatures as high as 1050°F., pressures to 2500 psi, use asbestos-filled GUARDIAN Gaskets.

GUARDIAN gaskets are another of the Garlock 2,000 . . . two thousand different styles of packings, gaskets, and seals for every need. The only complete line. Ask your local Garlock representative for his unbiased recommendations. Or, write for Folder AD-104.

THE GARLOCK PACKING COMPANY, Palmyra, New York

For prompt service, contact one of our 30 sales offices and warehouses throughout the U. S. and Canada.

*Registered Trademark †DuPont Trademark for TFE Fluorocarbon Resin

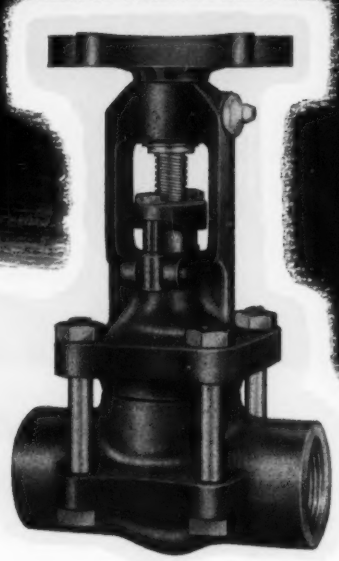
Canadian Division: The Garlock Packing Company of Canada Limited
Plastics Division: United States Gasket Company

GARLOCK

Packings, Gaskets, Oil Seals, Mechanical Seals, Molded and Extruded Rubber, Plastic Products

Announcing . . . a major break-through in valve design

OIC's NEW ½" to 2" ductile iron



PIPE PAL

GATE VALVES

See it at the Oil Show! It's an OIC *first!* OIC proudly introduces PIPE PAL, the first valve designed especially to put the advantages of ductile iron to work for you.

PIPE PAL fills the void in those applications where a more corrosion-resistant valve with greater thermal shock resistance has long been needed . . . applications where forged and cast steel have never fully met the need. OIC's advanced design makes full use of ductile iron's toughness, economy, and corrosion resistance.

PIPE PAL, in ½" to 2" sizes, features an entirely new design—no minor innovation—with proven performance characteristics that will make it well worth your while to review all your present valve applications, and find the spots where you can effect economies to fight the cost-price squeeze with PIPE PAL.

Pressure rating: Screwed 1000 psi at -20° F to 650° F. Flanged: 150 psi at 400° F. Test pressures: 2175 psi shell test. 1500 psi seat test.

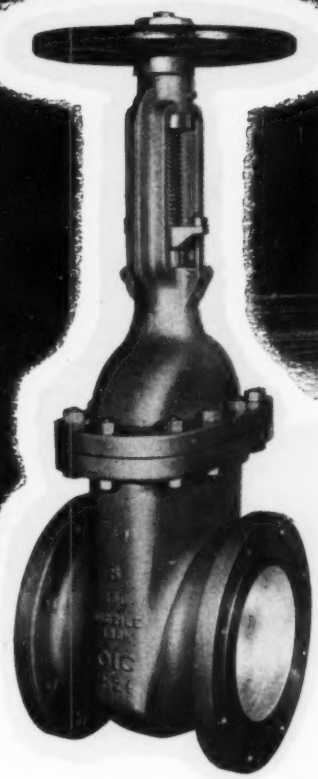
OIC VALVES | FORGED & CAST STEEL, BRONZE, IRON & DUCTILE IRON VALVES

The Ohio Injector Company • Wadsworth, Ohio

See it at OIC Booth 219, International Petroleum Exposition

Announcing... a major break-through in valve design

OIC's New 2" to 12" ductile iron



PIPE MATE

GATE VALVES

See it at the Oil Show! It's new! OIC proudly introduces PIPE MATE, the first valve designed specifically to give you all the proven advantages of ductile iron:

- Strength and toughness of steel
- Economy of iron
- Wear and corrosion-resistance you've been looking for

PIPE MATE, in 2" to 12" sizes, features an entirely new design—not a "remake"—engineered to meet the dimensional requirements of A. P. I. Standard 600.

Thorough testing has proved that PIPE MATE will resist corrosion better than steel, withstand thermal shock, and provide excellent wear. Yet the cost is considerably below the level of steel, to provide an exciting economic attraction.

Pressure rating: 220 psi at -20° F to 100° F. 150 psi at 400° F. 100 psi at 650° F. Test pressures: 425 psi shell test. 300 psi seat test.

OIC VALVES | FORGED & CAST STEEL, BRONZE, IRON & DUCTILE IRON VALVES

The Ohio Injector Company • Wadsworth, Ohio

See it at OIC Booth 219, International Petroleum Exposition

Gasoline Plant . . .

Built With An Eye To The Future!

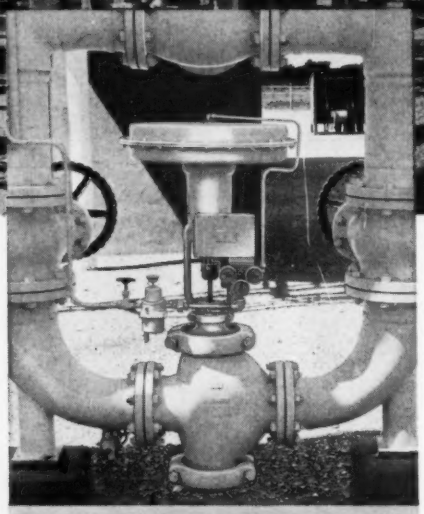
This modern absorption-type gasoline plant*, like most modern plants of today, was built with an eye to the future . . . with later expansion in mind.

Currently stripping 100 MMSCF of natural gas per day of propane, iso-butane, normal butane and natural gasoline, it can be quickly and inexpensively expanded to handle an additional 50% of its present capacity.

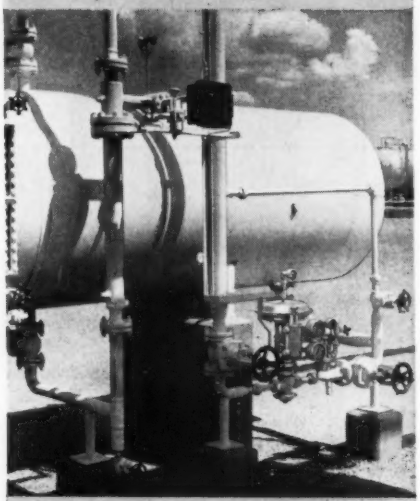
One very important reason for this plant flexibility was the incorporation in its design of wide range and capacity controls, such as BS&B Super 70 Control Valves, Liquid Level Controls and Regulators.

BS&B Controls are everywhere proving themselves in many different oilfield and other applications the world over. Why not specify them on your next job!

* Name and location supplied on request.



This 6", 150 lb. Super 70 serves as an accumulator pressure control valve. It is equipped with a direct acting actuator and valve positioner.



Butane splitter reboiler equipped with a BS&B Type 71-06 Series 2 Liquid Level Controller with automatic reset relay and a 1" Super 70 valve.

SUPER BS&B 70

BLACK, SIVALLS & BRYSON, INC.

Controls Division, Dept. 4-F5

7500 East 12th Street Kansas City 26, Missouri

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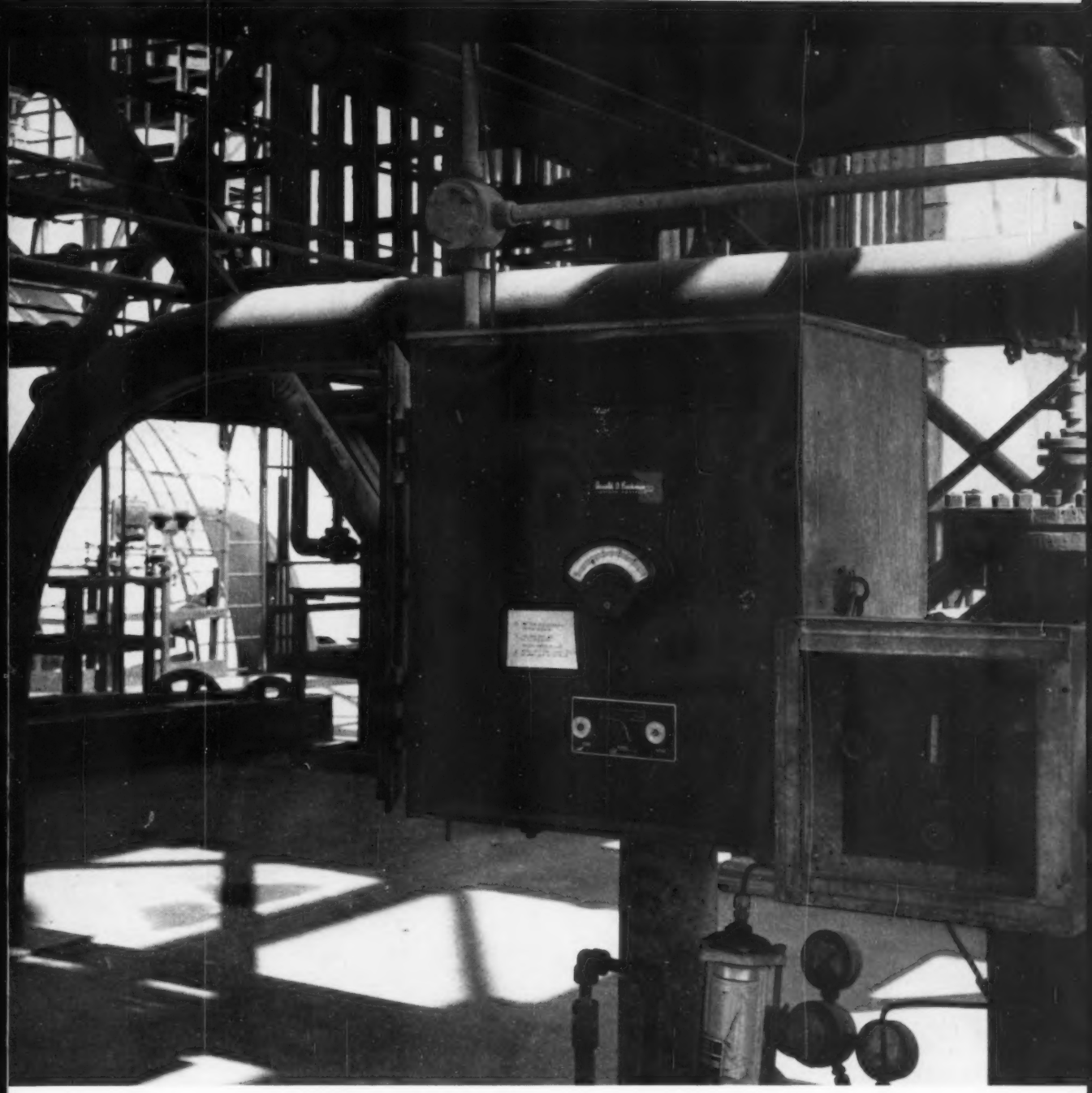


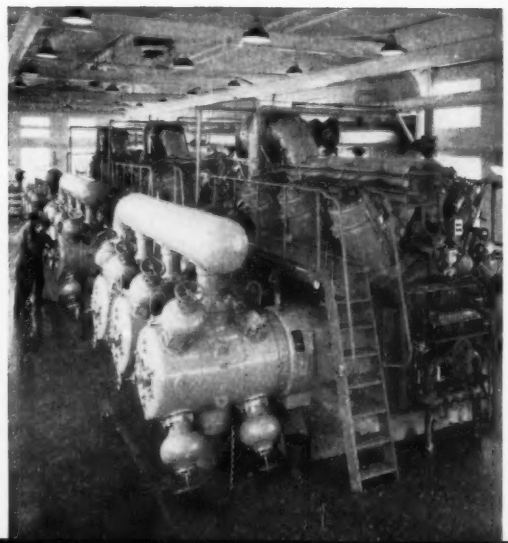
The sentinel that never gets relief... Day after day after day, for over 4 years this Beckman oxygen analyzer has maintained vigil on catalyst regeneration. Located eight stories above The Texas Company refinery at Wilmington, California, it has monitored unreacted oxygen, under demanding conditions, with only minimum routine maintenance. Analysis must be continuous, dependable, accurate. ⌘ This Beckman instrument is the only oxygen analyzer to use a direct paramagnetic measurement exclusively, which brings you these advantages: *Dependability...* under the most rugged conditions. *Simplicity...*with no auxiliary measurements to complicate analysis, no extra components requiring extra maintenance. *Accuracy...*with sensitivity and specificity to meet the most critical process requirements. ⌘ Whatever your application, if you want detailed specifications on an oxygen analyzer that withstands tough environments and gives you continuous, dependable answers, write for Data File 2P-6-25.

Beckman®
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road, Fullerton, California

It's a Fact: A Beckman Infrared Analyzer has successfully controlled heat input to a refining tower for three years, maximizing ethylene recovery and minimizing methane content by analysis of the bottoms of a demethanizing absorber.

Exterior view of Utica Station.

The three compact 6-cylinder Cooper-Bessemer GMVC Compressors are rated 1000 hp at 300 rpm. Two have been in service since 1957. One was added in 1959.



Victor G. Fulkerson, *Head Engineer, Utica Station, New York State Natural Gas Corporation, explains...*

How the new Utica Station meets growing demands with Cooper-Bessemer Compressors

"Our Utica Station was built in 1957 to boost gas pressure for the mounting demands of the Albany-Schenectady area. It housed two 1000 hp Cooper-Bessemer Series-Turbocharged V-Angle Compressors. Then, a demand for 20 million cubic feet more gas daily required the addition of a third unit of the same type and size this year (1959).

"Averaging about 85 million cubic feet per 24 hours, the station has pumped peak loads of as much as 140 million cubic feet. Entering the station at 400-700 psi, the gas is discharged at 600-900 psi."

FACTS ABOUT COOPER-BESSEMER SERIES-TURBOCHARGED V-ANGLE COMPRESSORS

Peak Load—Plus Capacity. Plenty of reserve power, always ready for those unexpected extra demands, provides a big economy advantage.

Low Fuel Consumption. Guaranteed not to exceed 7200 Btu/bhp-hr at full load!

Less Housing Cost. Compact V-angle design, combined with 40% power increase of series turbocharging, means today's highest power-to-space ratio, with no increase in piping or cooling requirements.

Minimum Oil Consumption. Cooper-Bessemer "cocktail-shaker" piston cooling, precision-honed cylinders, and advanced piston and ring design, combined with highly efficient, full-flow filtration, results in exceptional lube oil economy.

Low Maintenance. Many factors contribute to records of trouble-free performance—the simplicity of V-angle 2-cycle design, fewer moving parts, accessibility, conservative ratings, and, extremely significant, vibrationless operation.

Write For Bulletins. Complete details on Cooper-Bessemer V-Angle Compressors are given in bulletins... free on request. Call our nearest office to help you plan new facilities.

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tame HF for alkylation economies

...Pennsalt service helps you do it

Why not cash in on the advantages of hydrofluoric acid alkylation? Simple catalyst regeneration gives you lower acid consumption per barrel of alkylate . . . eliminates spent acid problems and large acid inventories. HF lets you use water as your coolant . . . reduces cooling equipment expense. It gives you shorter reaction time and catalyst settling time. Getting these economies is easy. Here's why.

Expert technical aid from Pennsalt shows you how to handle HF safely . . . just as safely as many other active chemicals you're already using. We'll advise you on HF storage, and on piping, valves and other equipment and materials . . . help you with employee training programs. We can give you this service because . . .

Pennsalt specializes in HF. We've pioneered in making, shipping and storing it better, safer and more economically. The purity of Pennsalt® HF meets or surpasses alkylation process requirements. Ample supplies are available, in cylinders and tank cars of convenient sizes. Write or call for more information or ordering.

See our Catalog in Chemical Materials Catalog

INDUSTRIAL CHEMICALS DIVISION

PENNSALT CHEMICALS CORPORATION

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Pennsalt Chemicals ESTABLISHED 1850

In the West, Pennsalt inorganic chemicals are available through Pennsalt of Washington Division, with plants at Tacoma, Washington and Portland, Oregon.

For more data on advertised products, use Readers' Service Cards, last page.

What we already know about your 1963 car

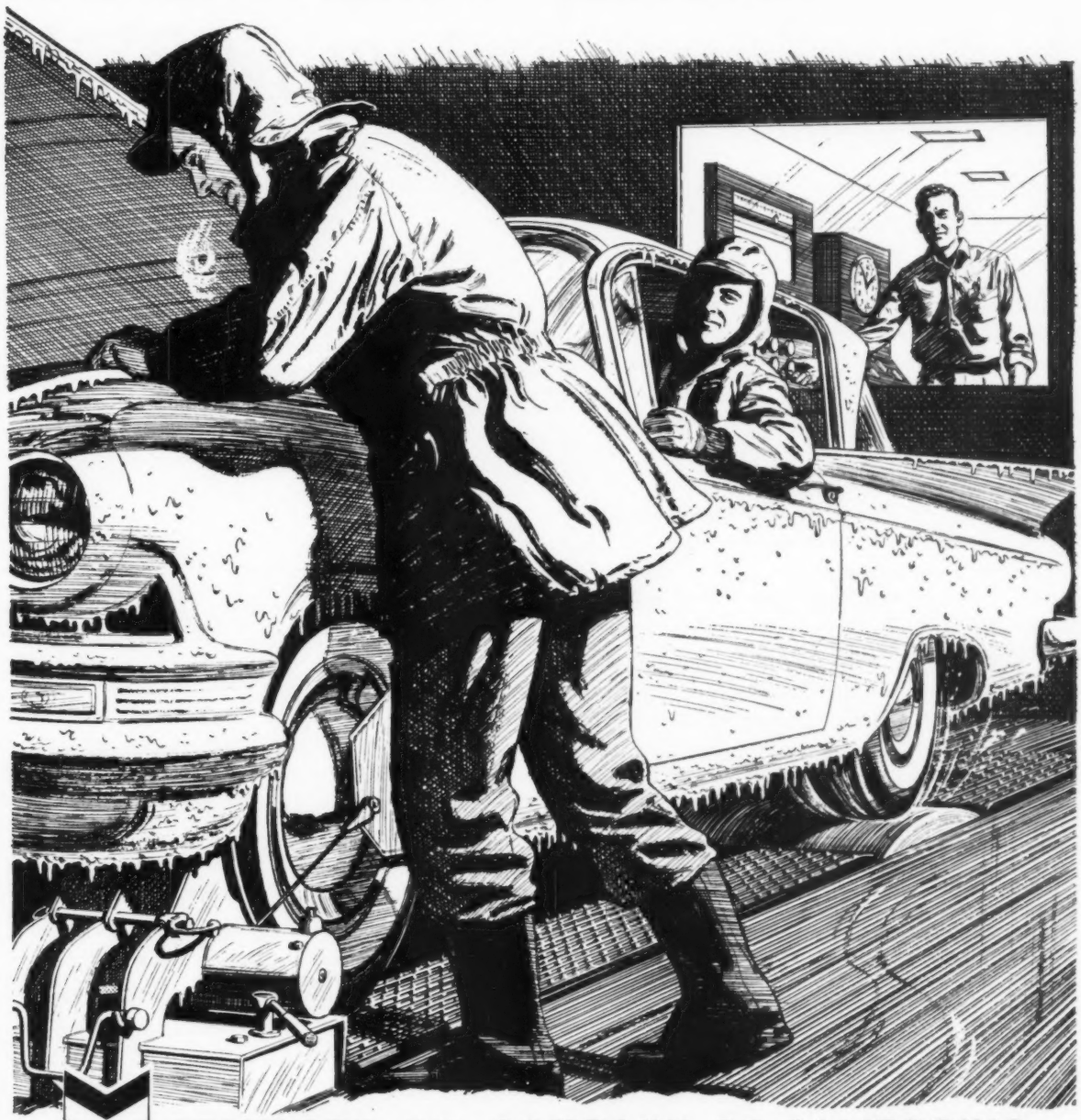
The engine of your 1963 car will be lighter and will give you improved performance . . . including better gasoline mileage.

We know this because Standard's scientists are already developing gasolines of the future. To test them, we use experimental engines installed in current model cars. The engines are obtained from auto makers and modified in our laboratories to match engine design forecasts.

These future fuels get the toughest possible workout — on the road, as well as on this "indoor highway." Here, at the touch of a button, we can create almost any kind of weather or driving situation a car might encounter.

Gasolines are tested at varying speeds and engine loads to simulate mountains, traffic and freeways . . . under climatic conditions ranging from 120° desert heat to 40° below zero cold.

Your car of the future may never take such punishment. But if it does, we'll be ready with gasolines that will deliver all the power and performance built into its engine. Research that leads to new and improved gasolines is one of the ways ***the people at Standard are planning ahead to serve you better.***



STANDARD OIL COMPANY OF CALIFORNIA

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What every chemical processor should know ...about NORTON

You can meet a *wide* variety of chemical and petrochemical processing requirements efficiently and economically with NORTON Products. They're more than just outstanding refractory materials. In addition, they provide versatile combinations of chemical, physical, and electrical properties that make them valuable aids at many critical stages of production. Find out how these advanced materials from the NORTON electric furnaces can help *your* operations by substantially improving process and product . . . sharply reducing operating costs. If you wish, the NORTON Man will be happy to discuss processing problems with you at any time. Backed by years of experience in the field, he's well qualified to help. Write NORTON COMPANY, Refractories Division, 464 New Bond Street, Worcester 6, Massachusetts.

FOR CATALYSIS

A full line of catalyst carriers to meet the requirements of a wide range of feedstocks and thermal conditions. For coated or impregnated use. Size, weight, porosity, pore diameter, and purity held to close tolerances to assure precise duplication of results.

SHAPES	*MATERIALS*	*POROSITY*
Spheres	Alumina	from 10% to 50%
Rings	Silicon Carbide	
Pellets	Fused Magnesia	*Surface Area*
Granules	Zirconia	
Powders	Silica, Zircon	From less than 1
	Magnesia-Alumina	to 70 M^2/gram*
	Spinel, etc.	

Bulletin No. 7 gives full details. *BET Method

FOR FILTRATION

A wide selection of porous media for filtration, diffusion, or aeration. Made of strong, chemically stable ALUNDUM* fused alumina, they also have high resistance to alkalies and acids. Provide uniform flow, with pores uniformly distributed in needed sizes and open-pore ratios. Tubes, plates, discs. Catalog No. 140 provides details.

FOR NUCLEAR WORK

Control and shield materials, including highly stable, lightweight NORBIDE* (B_4C). Metallurgical processing refractories. Ceramic fuel pellets. Source and intermediate materials.

FOR HIGH TEMPERATURE PROCESSING

Castables: Highly versatile, easy-to-handle ALUNDUM fused alumina materials for insulation. Provide protection up to 3300°F. Shipped dry in moisture-protective bags, they can be mixed in minutes. Small, lightweight bubbles or dense grains. Bulletin 1992 offers details.

Cements: Three different heat-resisting, chemically-inert materials carefully blended to assure proper grit-size distribution. ALUNDUM fused alumina, CRYSTOLON* silicon carbide, MAGNORITE* fused magnesia. For troweling, ramming, patching, pressing or brick-laying. Catalog 863 provides more information.

For more data on advertised products, use Readers' Service Cards, last page.

products

Ceramic Spray Coatings: Hard, crystalline materials which can be applied to a wide variety of base materials to provide thermal or electrical insulation, add mechanical strength, improve resistance to wear, corrosion, and chemical activity. ROKIDE* "A" aluminum oxide; ROKIDE "ZS" zirconium silicate; ROKIDE "Z" zirconium oxide. Bulletins available.

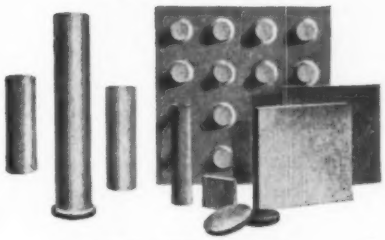
Fired Shapes: High-purity shapes of ALUNDUM fused alumina and fused stabilized zirconia offer excellent thermal insulation and chemical stability at high temperatures under both oxidizing and reducing atmospheres. CRYSTOLON silicon carbide products are available for processes involving heat transfer and abrasion resistance. Write for Catalog 862.

ALUNDUM ware has been used successfully for many years in laboratory development, experimental and analytical work involving filtering, extractions, melting, incineration, etc., because of its chemical resistance and stability in contact with reagents and solvents. Write for Catalog 793.

*Trade-Marks Reg. U.S. Pat. Off and Foreign Countries

NORTON
REFRACTORIES
Engineered... Rx ...Prescribed
Making better products...
to make your products better

FOR CATALYSIS



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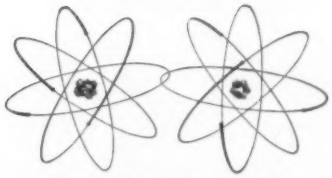
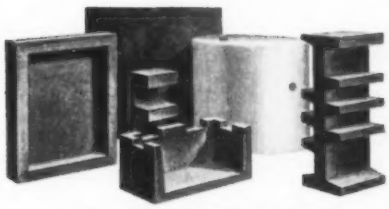


FOR NUCLEAR WORK



FOR HIGH TEMPERATURE PROCESSING

FOR THE LABORATORY

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FIFTH WORLD PETROLEUM
CONGRESS EXPOSITION
New York Coliseum — June 1–5
Space 76

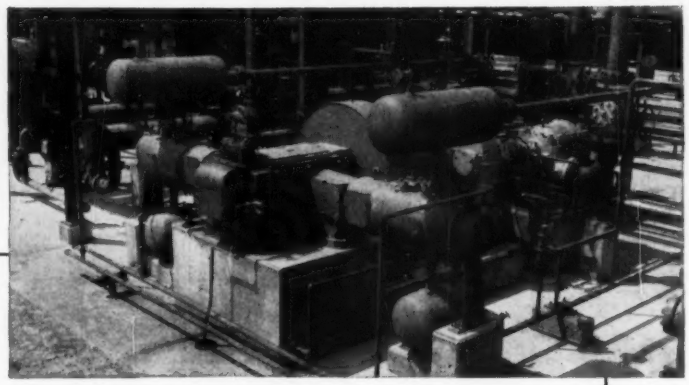
NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electro-Chemicals — **BEHR-MANNING DIVISION:** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

For more data on advertised products, use Readers' Service Cards, last page.

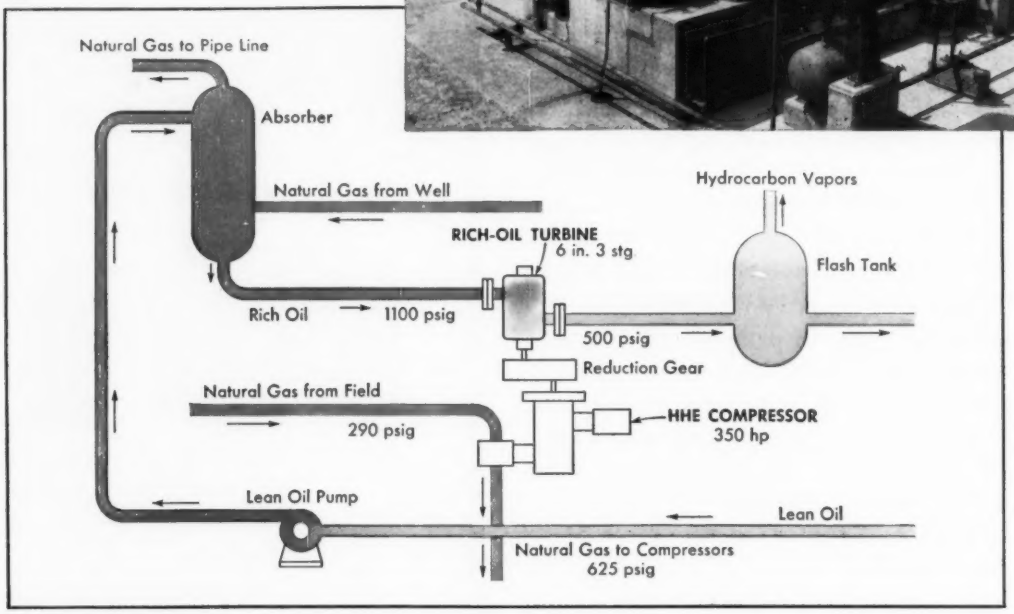
PUTTING "WASTE HORSEPOWER" TO WORK

By driving Ingersoll-Rand Compressors with I-R Rich-Oil Turbines, La Gloria Oil & Gas Company recovers 1000 hp

One of three Ingersoll-Rand HHE compressors driven by a 350-hp I-R 6-inch, 3-stage rich-oil turbine (shown at right) at the La Gloria natural gasoline plant.



Schematic flow diagram of the absorption cycle, simplified to show only one flashing stage. In this plant, three 350-hp turbines are installed between absorbers and high-pressure flash tanks, and two I-R 4-inch, 2-stage 150-hp turbines are located between high-pressure and low-pressure flash tanks.



IN the absorption process for natural gasoline extraction, rich oil from the absorber must be reduced in pressure before going to the still. This pressure reduction is usually accomplished by a reducing valve that does no useful work. But by putting an I-R *rich-oil turbine* in place of the reducing valve, other equipment can be driven by the horsepower recovered in the pressure reduction process.

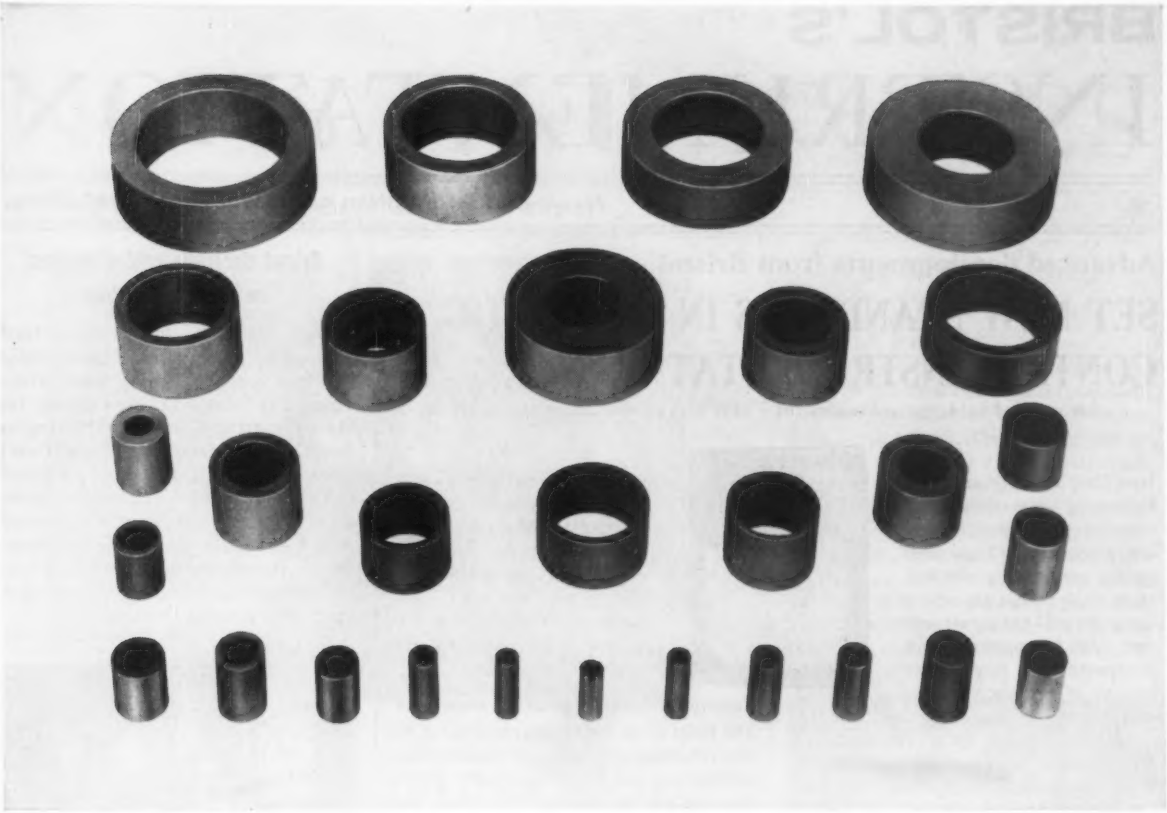
This "free" energy recovery is well illustrated at La Gloria Oil & Gas Company's plant near Corpus Christi, Texas. Here, three Ingersoll-Rand gas compressors are driven by I-R three-stage rich-oil turbines each of which is designed to recover 350 hp from its rich oil stream. As shown in the schematic diagram above, the compressors boost 290-psi gas from the absorber to 625 psi for further compression. The rich-oil turbine reduces pressure from 1100 psi to 500 psi, operating at 3350 rpm and driving the compressor through reduction gears.

Does *your* process plant have idle fluid horsepower that could be put to work? Your I-R representative will be glad to give you complete information on rich-oil turbines, compressors and pumps for any application.

Ingersoll-Rand

14-892 ♥ 11 Broadway, New York 4, N. Y.

PUMPS • COMPRESSORS • CONDENSERS • GAS AND DIESEL ENGINES • VACUUM EQUIPMENT • AIR AND ELECTRIC TOOLS • TURBO-BLOWERS



2 ways to save on pressure tubing

1. GET TIMKEN QUALITY STEEL

When you get Timken® steel pressure tubing, you get the finest quality tubing your money can buy. Quality that assures long, economical service. And it begins in the Timken Company mill with fine alloy steel, melted in the most modern electric furnaces in this country. Experts in melting, piercing, finishing and inspection guard this quality for you using many procedures that are virtually unique in the steel industry. For example, *all* tubes are specially conditioned to assure finer finish. And backing all this technical ability are *30* years of experience in producing pressure tubing. The result is quality that assures you *the longest tube life per dollar.*

2. LET TIMKEN COMPANY EXPERTS HELP SOLVE YOUR PRESSURE TUBE PROBLEMS

Whatever your steel pressure tube problems—corrosion, oxidation, heat, pressure—Timken Company steel experts can help solve them. They've solved hundreds of the toughest problems in every field, from steam generators to chemical plants. From the wide range of diameters and wall thicknesses available in Timken pressure tubing, (typical examples shown above) we can select the most economical size in the right analysis for your needs.

Get quality pressure tubing that will save you money. Specify Timken steel pressure tubing. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.*

WHEN YOU BUY TIMKEN STEEL YOU GET . . .

1. Quality that's uniform from heat to heat, bar to bar, order to order
2. Service from the experts in specialty steels
3. Over 40 years experience in solving tough steel problems

Visit us at the INTERNATIONAL PETROLEUM EXPOSITION, May 14-23, 1959—Booths 139-142, Oklahoma Building, Tulsa, Oklahoma.

TIMKEN® *Fine Alloy* STEEL

TIMKEN ALLOY STEEL AND SEAMLESS TUBING IS AVAILABLE FROM WAREHOUSE STOCK IN 44 CITIES IN THE UNITED STATES

For more data on advertised products, use Readers' Service Cards, last page.

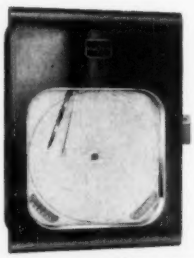
BRISTOL'S INSTRUMENTATION

★ *News and information about automatic controlling,*

Advanced developments from Bristol

SET NEW STANDARDS IN PNEUMATIC CONTROL INSTRUMENTATION

• assure dependable accurate control • easy servicing • convenience in use



New ideas at Bristol are revolutionizing some of the older concepts of pneumatic control instrumentation. These giant strides are making obsolete many designs that are only a few years old—but are already outmoded by modern Bristol equipment that gives better control of process variables and sets new standards for dependability.

Take, for example, the new Bristol Series 500 Wide-Band Pneumatic Controllers. These recent products of Bristol engineering and development are outstanding for stability of output on difficult process-control problems. They incorporate many advanced features, such as reset action stops and a true zero derivative setting, which are found on no other line of pneumatic controllers.

Best maintenance record

Basic simplicity, accurate design, closely held manufacturing tolerances make one single adjustment all that's necessary on the Bristol 500—even after complete disassembly and reassembly with replacement parts.

This practically "built-in" calibration is typical of the foresight and engineering planning that make the Series 500 the easiest pneumatic control system on the market to service. Cut-and-try methods are eliminated. No special maintenance skills are required. All parts are completely interchangeable. The result: a truly superlative maintenance record in thousands of industrial plants.

Famous Bristol measuring elements

The heart of an instrument, whether it be for recording, controlling, or telemetering, is its sensing and measuring system. That's why, for the 70 years of its existence, the Bristol Company has thrown its resources into the development of measuring systems.

Today, Bristol has longer, wider experience in this field than any other instrument company. Bristol leadership in measuring elements is recognized and respected the world over.

Bristol instruments come with the widest selection of high-quality measuring elements available for any line of instruments. **Temperature, pressure, vacuum, draft, absolute pressure, liquid level, flow, humidity, density, pH, are just a few of the variables that can be measured—plus a large number of other variables measurable with air-controlling electronic potentiometers and bridges.**

SEVERAL HUNDRED STANDARD MODELS MEET EVERY PROCESS REQUIREMENT INCLUDING:

These problems:	These operating modes:
1. Cascaded control	1. Fixed narrow band (on-off)
2. Selective control	2. Proportional—to 100% and to 30%
3. Ratio control	3. Reset with wide band—to 400%
4. Time program control	4. Derivative (rate)
5. Pneumatic transmission	5. Reset plus derivative

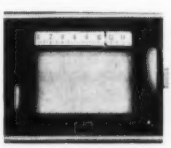
Bristol electronic control assures uniform ceramic tiles

Uniform size, color, texture and strength of ceramic tiles depend, among other things, on exact control of firing temperature. That's why Orange County Ceramic Tile Manufacturing Company, Huntington Beach, Cal., makers of the brilliant SUNSET tile line for home and industry, use Bristol Dynamaster* Electronic Pyrometers for accurate automatic control of kiln temperature. Precision automatic control insures an exceptionally uniform product and frees skilled production line supervisors from the need of constant checking.

T.M. Reg. U. S. Pat. Off.

Electrical measurement with air control, electrical control, digital or analogue read out

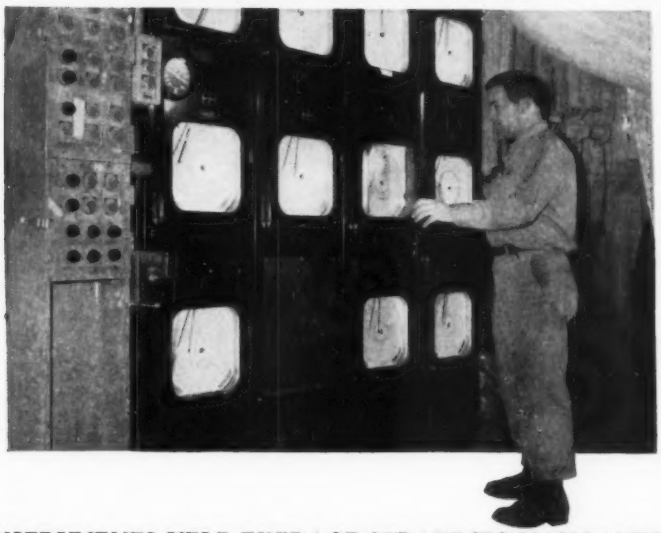
Bristol Dynamaster* potentiometer and bridge instruments are the most widely versatile electronic instruments on the market today. Models are available not only for precision pyrometry with thermocouples, radiation pyrometers or resistance thermometers, but for measurement, recording and electrical or air control of pH, speed, voltage, current, power, resistance, strain-gauge output and many other variables. An extremely wide variety of attachments and accessories is available—including auxiliary transmitting devices, digital encoders, alarm contacts, etc. Round or Strip charts (see photos below). Most models available for standard 19" relay rack-mounting.



For more data on advertised products, use Readers' Service Cards, last page.

NEWS AND NOTES

recording and telemetering instruments from Bristol ★



INSTRUMENTS HELP EXTRACT STRATEGIC MANGANESE

These Bristol Series 500 recorders and recorder-controllers are keeping tabs on the exclusive manganese extraction process used by Manganese Chemical Company, Riverton, Minnesota, one of the few domestic producers of chemical manganese compounds. The Bristol air-control instruments monitor reducing gases, cooling gases, indicate leach liquor liquid levels and record vital temperatures in the production process. The plant is in operation 24 hours a day, 7 days a week and the Bristol 500's stand up to this grueling service with the same outstandingly high reliability that they are showing in hundreds of other chemical plants throughout the world.

500's CONTROL OIL TEMPERATURE FOR STEEL ROLLING

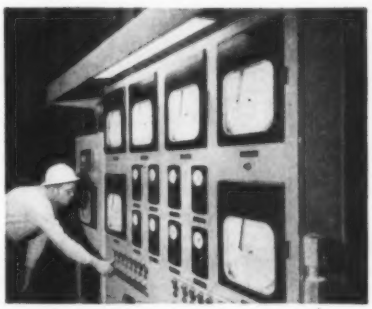
These Bristol Series 500 instruments are two of a number used to control the temperature of lubricating oil supplied to the rolling mill main bearings on the number one rod mill at the Cuyahoga Works of U. S. Steel's American Steel & Wire Division.

The instruments maintain temperature of the lubricants at 100°F for the entire system by controlling the amount of cooling water being used.

Bristol Series 500 instruments are noted for their excellent maintenance record under severe environmental conditions, can be maintained without special skills, special tools. What's more, Bristol service engineers, operating out of the main plant, four branch plants, and from 44 principal cities, are available to help you apply series 500's (or any Bristol instruments) and assure you of their long, continuous, trouble-free service.

3 big reasons for air-control in this plant

Sometimes it's a toss up between air or electronic control. Not so in Lithium Corporation of America's Bessemer City, North Carolina, plant for extraction of lithium from low-grade ore. Three cogent reasons suggested air control for a large part of this operation: (1) positive pressure of 15 to 20 psi would protect the system from humidity, dust and corrosive fumes, (2) short transmission lines (none longer than 1100 ft., most only 200 to 300 ft.) would insure positive, lag-free operation and (3) cost of an air-control system for their $7-million plant was estimated at only $150,000 to $200,000.



Have any doubts about what control system you should use? Get Bristol's absolutely unbiased recommendation: As makers of *all types* of electronic and pneumatic process control instruments, Bristol is in a unique position to help you get the instrumentation that's exactly right for your needs. B 49

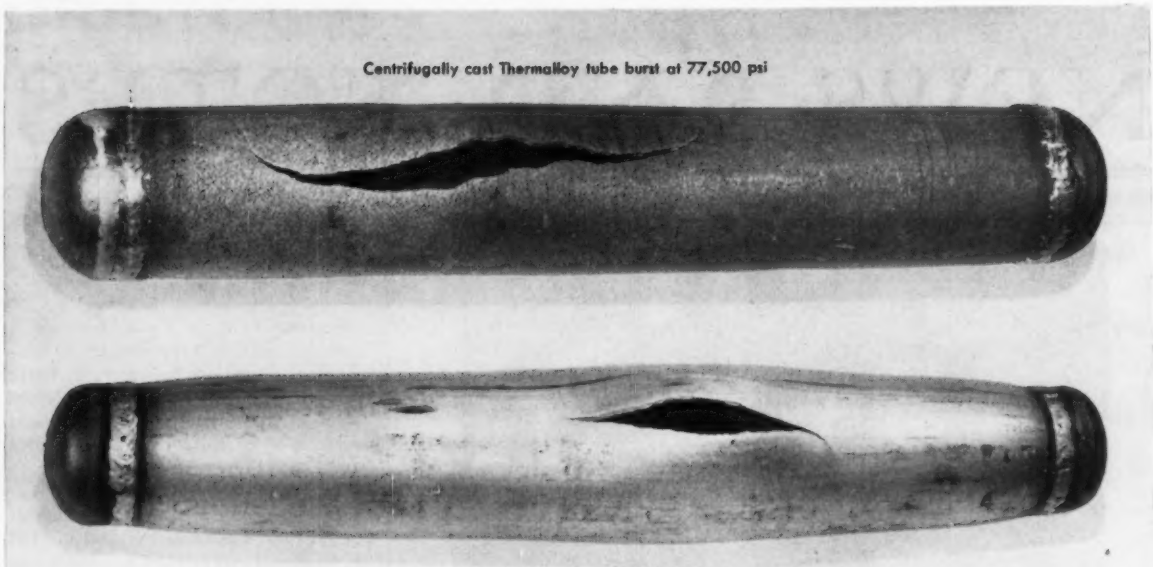
ASK FOR COMPLETE DATA

We'll be glad to send you complete technical information on any Bristol instrument. Or trained Bristol field engineers, familiar with the problems of your industry, will welcome the opportunity to discuss a complete, integrated system of measurement, recording or control—pneumatic or electronic—for your plant. Write The Bristol Company, 111 Bristol Road, Waterbury 20, Conn.

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

For more data on advertised products, use Readers' Service Cards, last page.



Centrifugally cast Thermalloy tube burst at 77,500 psi

Wrought tube burst at 70,100 psi

Burst tests prove 7,400 psi superiority of centrifugally cast Thermalloy® tubes

Hydrostatic pressure tests by Electro-Alloys established the rupture of a centrifugally cast Thermalloy tube section at 77,500 psi. Under the same conditions, wrought tubes of comparable section and analysis burst at 70,100 psi. These tests were conducted at room temperatures. Tensile tests show this strength margin increases substantially at the higher operating temperatures (1500° — 1800° F). The Thermalloy tube was tested *as cast*— without machining the inside or outside diameter. For further data, call your representative, or write Electro-Alloys Division, 1035 Taylor Street, Elyria, Ohio.

Study these tubes at the Fifth World Petroleum Congress Exposition, Booth 594, New York Coliseum, June 1-5.

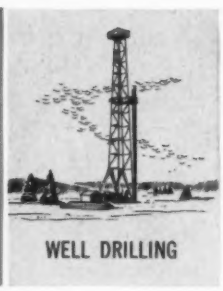
AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

For more data on advertised products, use Readers' Service Cards, last page.

Layne

the only complete water service organization



Complete service means undivided responsibility

In an age of specialization there is a definite advantage in doing business with a company offering a COMPLETE SERVICE . . . providing *all* the services allied to the field of water.

Only Layne with its network of Associate Companies, and over 75 years of experience, all backed by Layne Research can offer its customers a complete water service which makes Layne unique in the industry.

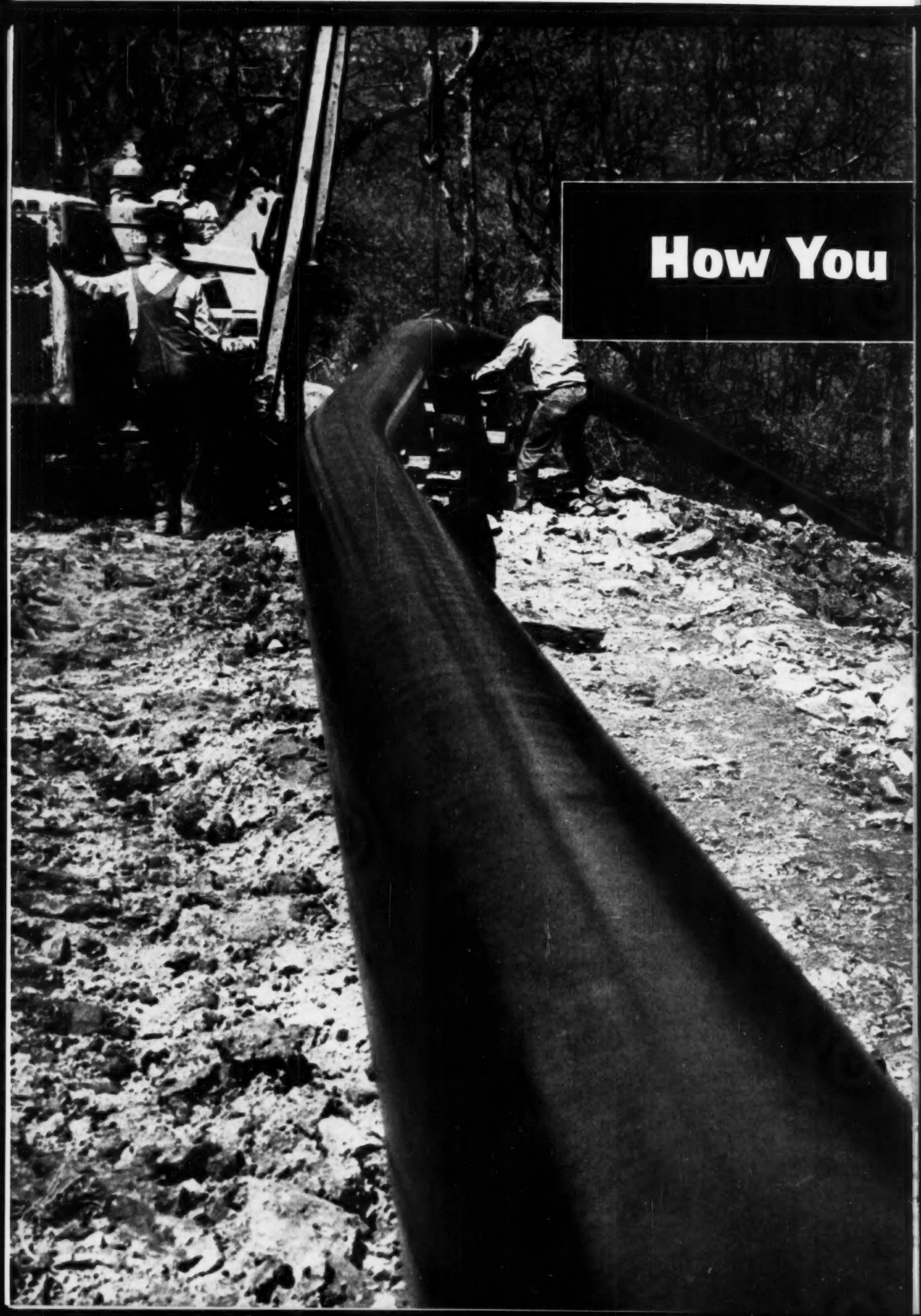
World's Largest Layne *Water Developers*

LAYNE & BOWLER, INC., MEMPHIS

Offices and Factory • Memphis 8, Tenn.

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

For more data on advertised products, use Readers' Service Cards, last page.


How You

Profit From Multiple Testing

Multiple testing of every length of **J&L Electricweld Line Pipe** is your assurance of better performance during installation and operation.

(1) Every length is pressure-tested under the specified A.P.I. or A.S.T.M. hydrostatic test requirement both in time and in degree of pressure. Pneumatic hammers strike the pipe while it is under pressure to build up pressure surge.

(2) A series of visual inspections is made on each length of **J&L Electricweld.**

(3) Each length of pipe is given a crush test to determine weld strength and steel quality. The test complies with requirements of A.P.I. 5L, 5LX and with A.S.T.M. A-53, A-135 and equivalent specifications.

(4) Both ends of each joint of **J&L Electricweld Line Pipe** receive a magnaflux examination.

Discover how you can profit by using this high quality pipe in your next line by calling your local J&L Supply man today. Remember if it's sold by J&L . . . it's the best available.

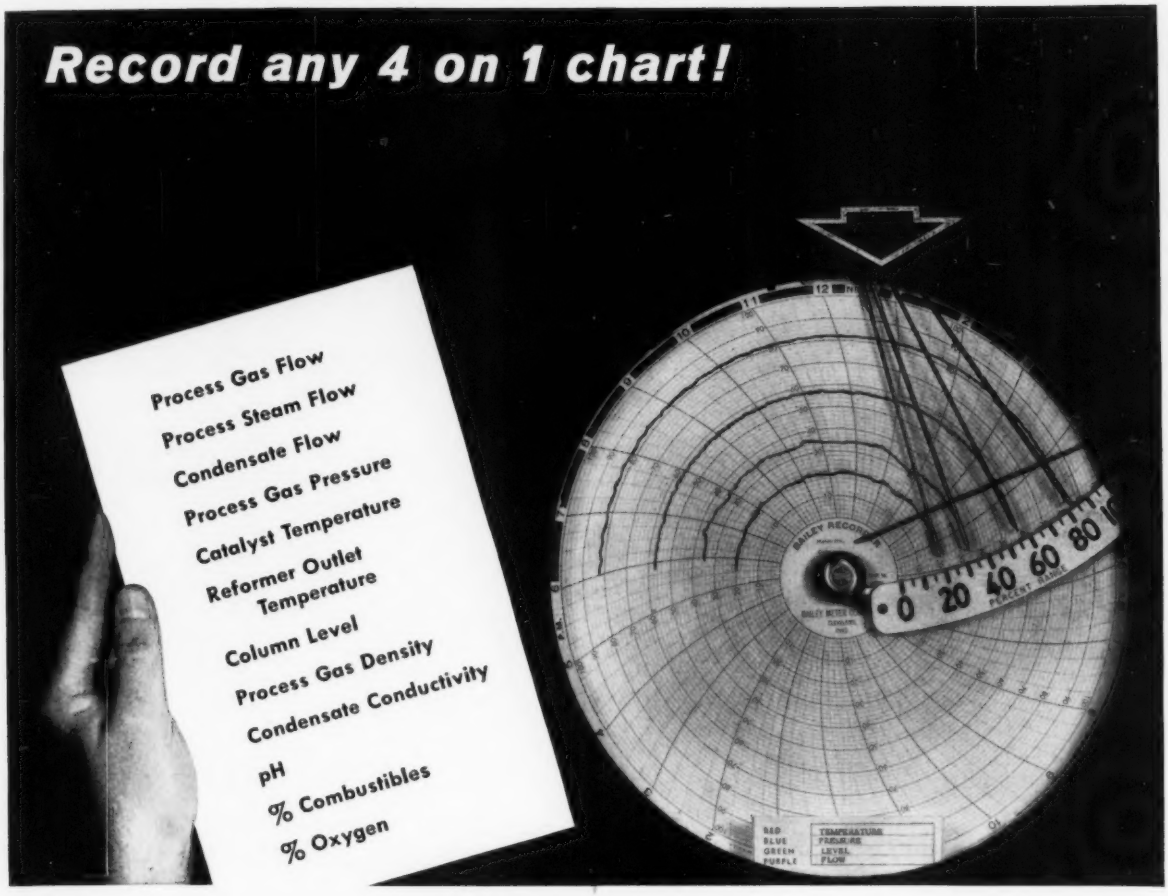
J&L Electricweld is available in sizes 6⅝" O.D. through 12¾" O.D.

Jones & Laughlin

SUPPLY DIVISION – Tulsa

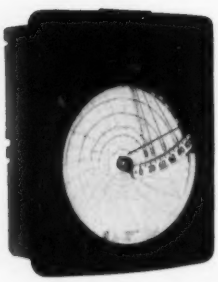
If it's sold by J&L . . . .
It's the best available

67



To give your operation "FOUR-IN-ONE" efficiency...

The BAILEY Receiver Recorder-Controller!



Records four variables on one chart.

You can lower the cost of your equipment investment and increase the efficiency of your entire operation with the Bailey Receiver Recorder.

HERE'S HOW

The interchangeable components for the Recorder make it fast, inexpensive, and automatic to do up to *four* measuring jobs at the same time with either or both pneumatic and electric systems.

This Bailey unit continuously and simultaneously records four variables on the same chart. And, they are *in the same linear scale measurement.* You have clear, easy-to-read records for continual analysis and control.

Plug-in, pre-calibrated receivers can easily be adapted on-the-job to revised process requirements. The Bailey Receiver Recorder saves you money with a minimum instrument investment for process cycle expansion or alteration. Let your local Bailey engineer suggest applications to fit your operation. Or write for specific control systems information for your entire plant operation.

CP105-1

Chemical and petroleum division

BAILEY METER COMPANY

1043 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

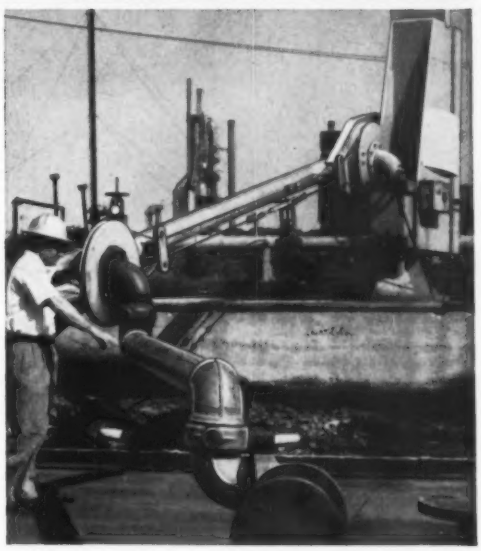
CHIKSAN

PREVENTS LINE HANDLING INJURIES
SPEEDS BARGE LOADING
ELIMINATES HOSE BURSTS
SLASHES REPLACEMENT COSTS

The Chiksan Barge Loading Arm ends hazardous manhandling of loading hoses, eliminates dangerous dock clutter. Mechanical operation makes hookup fast and simple.

Gear reduction enables one man to adjust the flange position anywhere in a 105° vertical range. Outboard arm is manually swung into position at any point in a 130° horizontal arc. The eight inch model rotates 360° to permit servicing barges on both sides of a narrow dock. Once hookup is made, the arm can be left unattended while free wheeling allows the unit to ride free during loading and unloading. When not in use, the arm is raised up and out of dockside traffic.

6″ x 25′ and 8″ x 28′ sizes available. Handle petroleum products, both black and bright, and mild caustics in any temperature ranging between —60° F. to +225° F. Service all river and lake barges and lake tankers including those in 25,000 barrel class.



The Chiksan Barge Loading Arm is designed to reach approximately 20 feet from dock riser to barge flange. Total length of Arm is 25 feet.

fmc CHIKSAN
A SUBSIDIARY OF
FOOD MACHINERY AND CHEMICAL CORPORATION

CHIKSAN COMPANY — BREA, CALIFORNIA
CHICAGO 5, ILLINOIS • NEWARK 2, NEW JERSEY
Well Equipment Mfg. Corp. (Division), Houston 1, Texas
Subsidiaries: Chiksan Export Company
Chiksan of Canada, Ltd.

58-36

CHIKSAN COMPANY
330 No. Pomona Ave., Brea, Calif.

Please send me your Barge Loading Arm Bulletin #456.

Name_____
Title_____
Company_____
Address_____
City_____ Zone____ State_____

For more data on advertised products, use Readers' Service Cards, last page.

For the best in outdoor flooring

Specify BLAW-KNOX Electroforged® Steel Grating and Treads

For safe, all-weather, outdoor flooring, made to take punishment and stand the strain, specify Blaw-Knox Electroforged Steel Grating and Treads. Proven on outdoor installations in all parts of the world, Blaw-Knox grating has an established reputation for quality, durability, and safety.

Easy installation—rigid one-piece construction fits readily around pipes, beams, and equipment.

Maximum load bearing capacity—Electroforging eliminates slotting or otherwise weakening bearing bars . . . one-piece construction increases structural strength.

Safest walking surface—non-slip, twisted crossbar plus choice of two types of bearing bars. Square, for smoothest walking surface . . . serrated, for maximum safety under extremely hazardous conditions.

Self-cleaning—Electroforged construction leaves no sharp angles to clog with dirt or grease. Being open, rain water usually provides all the cleaning necessary. Maximum open area allows light for working beneath floor.

Blaw-Knox has the grating and treads best suited to your needs. For information on how to specify and order, send for your copy of Blaw-Knox Bulletin number 2527.

BLAW-KNOX

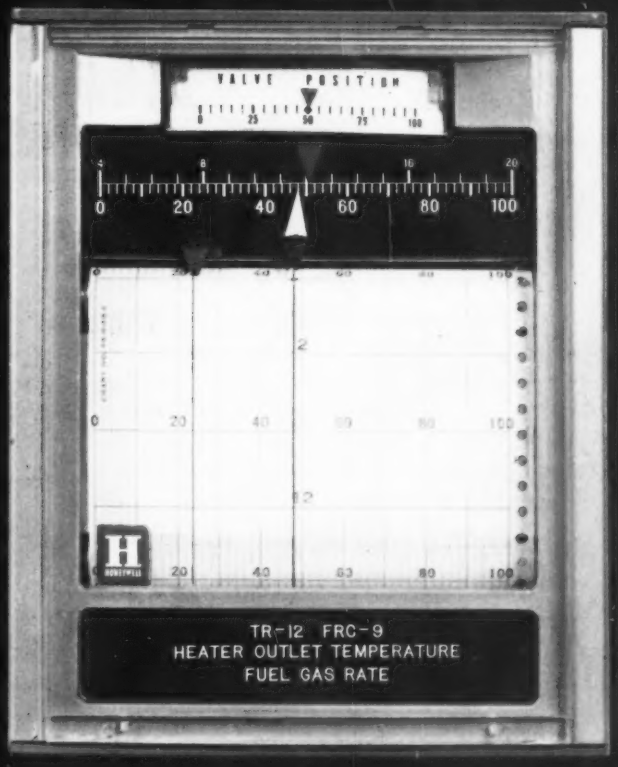
BLAW-KNOX COMPANY
Equipment Division
Dept. D, Pittsburgh 38, Pennsylvania

For more data on advertised products, use Readers' Service Cards, last page.

Here it is!

Honeywell's new *ElectriK Tel-O-Set system**

...the only true two-wire system for electric process control!



No line power connections in the field. The *ElectriK Tel-O-Set* system requires no external power at any field-mounted device and uses only two wires between it and the control room. These two wires form a series circuit that carries the measurement or control signal as well as the system's power. The only line power connection is made at the receiver.

Two-wire transmission sharply reduces installation costs. Add this to the fact that the *ElectriK Tel-O-Set* system's d-c transmission eliminates the need for shielding the wires, and you have the simplest, most economical installation possible.

*Trade name, Minneapolis-Honeywell Regulator Company

H HONEYWELL

COMPARE *ElectriK Tel-O-Set* WITH ANY OTHER ELECTRIC CONTROL SYSTEM!

Here it is!

the new *ElectriK Tel-O-Set* system

. . . newest advance in industrial process control

A complete, integrated line . . .

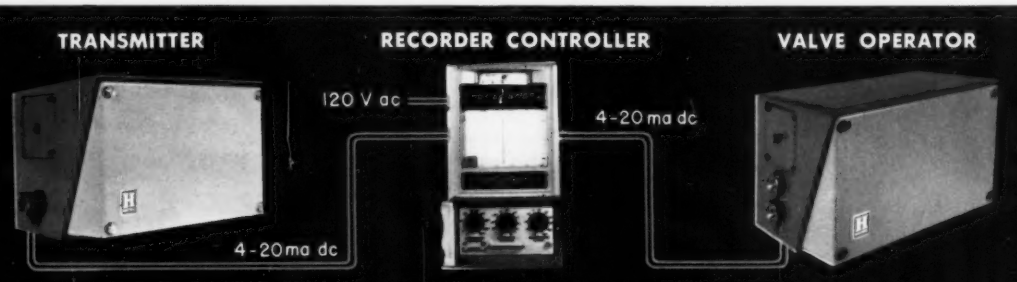
Control *any* industrial process with the *ElectriK Tel-O-Set* system. It has been designed as a complete system, rather than as a collection of individual instruments. The line consists of 22 major units which permit local and centralized data presentation, adjustable cascade control, ratio control and many other auxiliary functions. *ElectriK Tel-O-Set* transducers make the line completely compatible with your present pneumatic instruments.

. . . built for industry

Die-cast aluminum cases and stainless steel components are used throughout the line to withstand the rough handling and demanding environments of industrial applications. Standardized components, together with extensive use of quick-connect and plug-in design, mean ready interchangeability of parts, reduced spare parts inventory, easy maintenance. The modular, or "building block" concept is employed throughout for maximum flexibility.

. . . this is how it works

The basic *ElectriK Tel-O-Set* system consists of a transmitter, receiver, controller and final control element. The transmitter measures any process variable, translates it into a standard 4 to 20 milliampere direct current signal, and transmits to the receiver through a pair of copper wires. The receiver indicates or records the signal in terms of the actual value of the process variable, compares it with a pre-determined set-point, and sends the difference to the controller as an error signal. The controller then converts this into a corrective 4-20 milliampere output to operate the control valve—again transmitting over a single pair of copper wires.



All process and external electric connections to *ElectriK Tel-O-Set* field-mounted transmitters are entirely isolated from inside the case . . . to permit installation without the need for instrument department supervision.

All receivers, from single-point indicator without control to two-pen ratio-cascade control station, are housed in the same case and all use the same panel cutout of 5½ x 6 inches. Controllers can be mounted with adjustments in front or back of panel.

All *ElectriK Tel-O-Set* field-mounted units . . . whether transmitter, transducer, or valve actuator . . . operate at ambient temperatures of —40 to 150° F. They all work on the same force-balance principle and use many similar components.

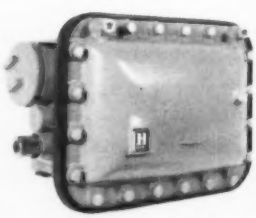
CHOICE OF THREE CASES

For field-mounted *ElectriK Tel-O-Set* units: Weatherproof for Division 2 locations; relay rack for mounting four abreast in a 19-inch rack, and explosion-proof for Division 1 locations.

All are completely transistorized and have quick-connect electric and pneumatic plugs.

Weatherproof

Relay rack



Explosion-proof

FR 2800a 471M

SYSTEM COMPONENTS

TRANSMITTERS
Process pressure to current (PP/I)
Differential pressure to current (Δ P/I)
Millivolt to current (MV/I)

RECORDERS
Single or two-pen recorders. Single or two-pen recording controllers with control, including simple cascade, on one pen. Two-pen recording controllers with ratio or cascade control on one pen.

INDICATORS
One pointer, with or without control
Milliammeter, with or without manual loading

CONTROLLERS
Two mode and three mode

FINAL CONTROL ELEMENTS
Current to pressure (I/P) valve operator
Electro-pneumatic positioner
Electro-hydraulic actuator

TRANSDUCERS
P/I: 3-15 psi to 4-20 ma dc
I/P: 4-20 ma to 3-15 psi
I/F: 4-20 ma dc to frequency
F/I: frequency to 4-20 ma dc

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL
21 Penn Street, Fall River, Mass.

Honeywell

First in Control

Case Type No. 1279.

Case Type No. 1379 is Alumalife, while similar case Type No. 1079 is Cast Iron.

Case Type No. 1377.

In such cases DURAGAUGES® naturally serve longer

You have a choice of three case materials—Alumalife®, a special aluminum alloy, Cast Iron, rugged and durable, Phenol, tough and rigid plastic—plus the unique "Maxisafe" design when you specify Ashcroft Duragauges.

All three case materials use a chrome plated, die-cast retaining ring to keep out harmful fumes and dirt. Case construction simplifies servicing—the entire system can be easily removed for recalibration or repair.

The "Maxisafe" case provides absolute protection to the viewer, easy and quick access to the tube and movement assembly. An integrally cast solid wall separates the dial from the tube and movement. A safety cover plate on the back is held in position by a knurled knob.

Regardless of your gauge case requirements, there's an Ashcroft Duraguage to do the job. Contact your local Ashcroft Gauge Distributor for complete facts.

Ashcroft Duragauges are available in pressure ranges from 15 psi (or vacuum) minimum to 100,000 psi.

CASE MATERIALS, TYPE NUMBERS, MOUNTING AND SIZES

CASE	TYPE NO.	BACK FLANGE	MOUNTING		CONNECTION		DIAL SIZE
			WALL	FLUSH	LOWER	BACK	
Black Alumalife	1379	Yes	Yes	Yes	Yes	Yes	4½", 6"
Black Cast Iron	1079	Yes	Yes	Yes	Yes	Yes	4½", 6", 8½" 10", 12"
Black Phenol, Turret Design	1279	No	Yes	Yes*	Yes	Yes	4½", 6", 8½"
Black Alumalife**	1377	No	No	Yes	No	Yes	4½", 6", 8½" 10", 12"

**May be flush mounted by using Flush Mounting Ring, Catalog No. 1278.*
***The 10" and 12" dial sizes are made in cast iron only.*

MANNING MAXWELL & MOORE INC. TRADE MARK

ASHCROFT PRESSURE GAUGES

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

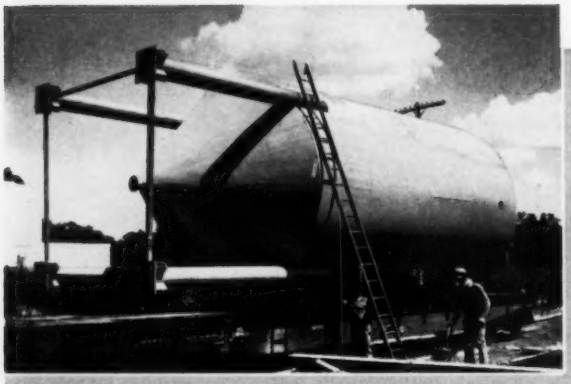
For more data on advertised products, use Readers' Service Cards, last page.

In Custom Fabrication of

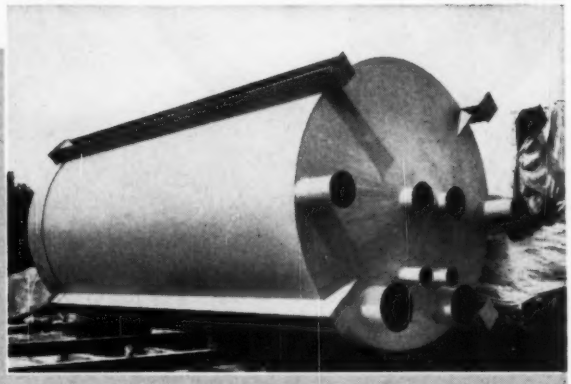
CODE TANKS and PRESSURE VESSELS

there is no substitute for *Experience*

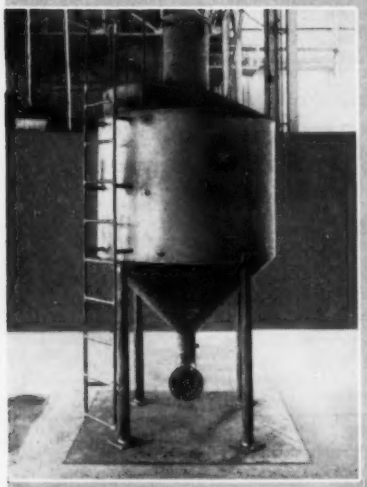
Modern Welding offers a wealth of experience in custom fabrication. Our well equipped strategically located plants serve chemical processing and petroleum industries throughout the world. Our facilities are at the disposal of the men who design, construct, operate and maintain processing plants.



Sludge Settler tank for petrochemical plant is the first in this revolutionary new design.



Dual purpose phenolic-lined polyethylene storage tank with structural reinforcements.



Calibration and prover tank for measuring the accuracy of pipeline crude oil meters.

Air receiver tanks for compressor stations. Pressure tested in 450 lbs. of hydrostatic pressure conforming to A.S.M.E. 1952-A code. Each X-ray tested.

MODERN TANKS QUALITY

MODERN WELDING COMPANY

INCORPORATED

Owensboro, Kentucky

NEWARK, OHIO · ORLANDO, FLA. · HOUSTON, TEXAS · BURLINGTON, IOWA

SAVE
maintenance

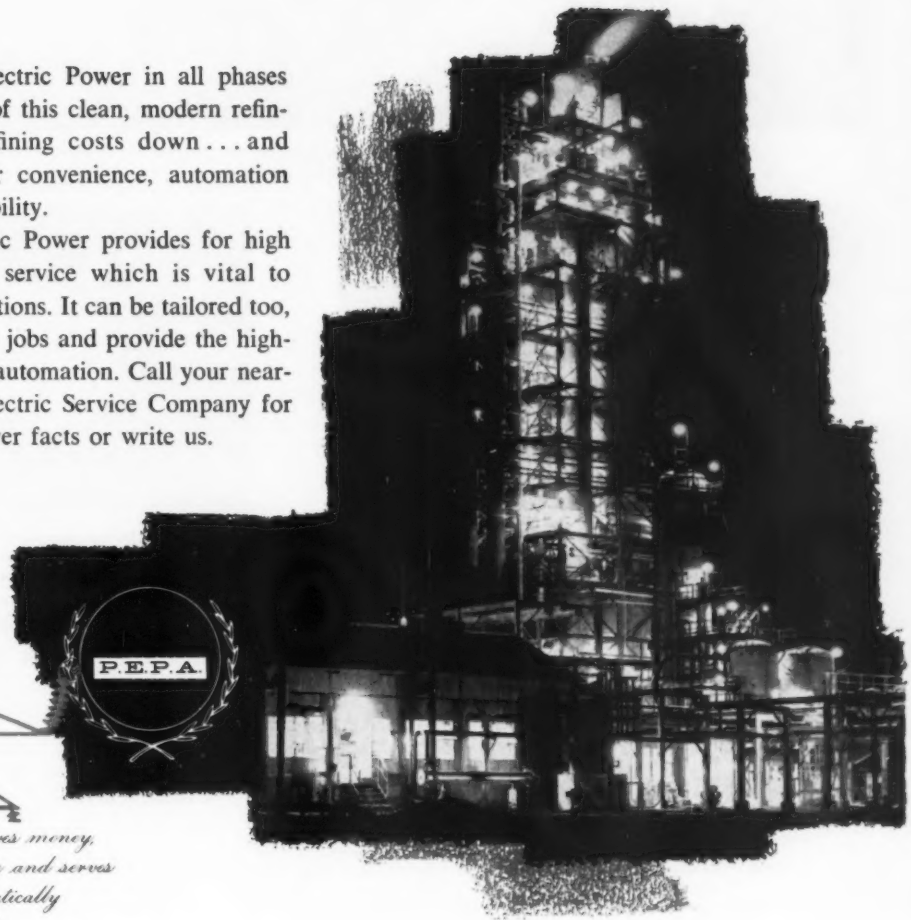
SAVE
manpower

SAVE with Electric Power

SAVE
money

Purchased Electric Power in all phases of operation of this clean, modern refinery holds refining costs down . . . and means greater convenience, automation and dependability.

Utility Electric Power provides for high continuity of service which is vital to refining operations. It can be tailored too, for individual jobs and provide the highest degree of automation. Call your nearest Utility Electric Service Company for complete power facts or write us.

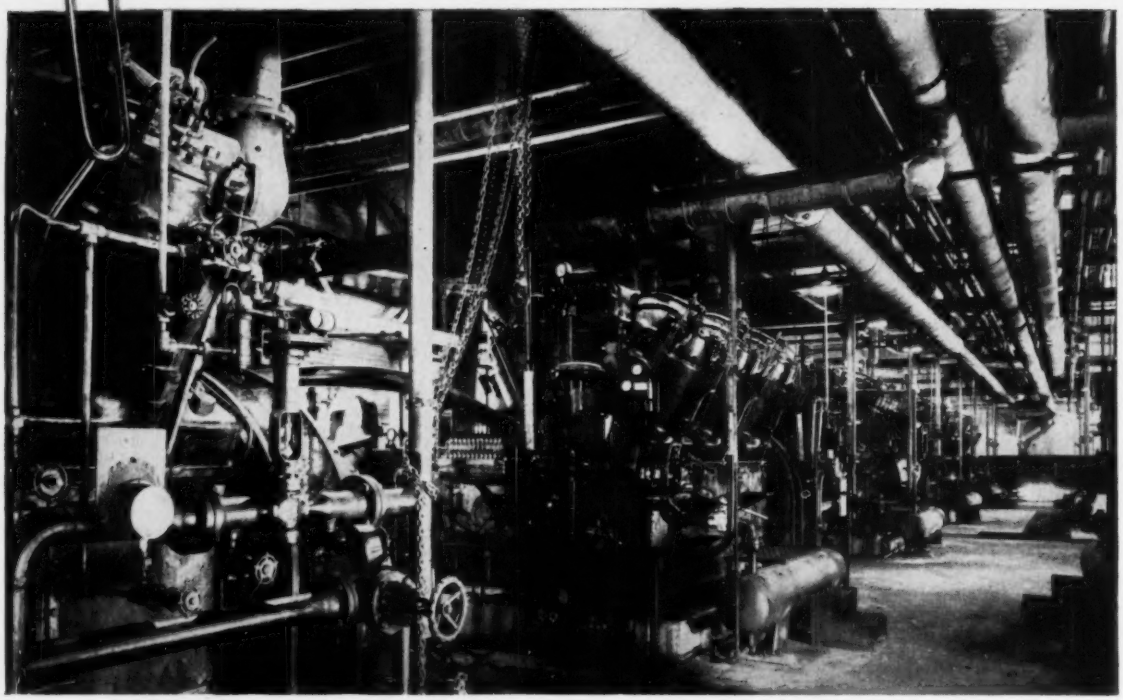


Electric Power . . . saves money, manpower, maintenance and serves you better automatically

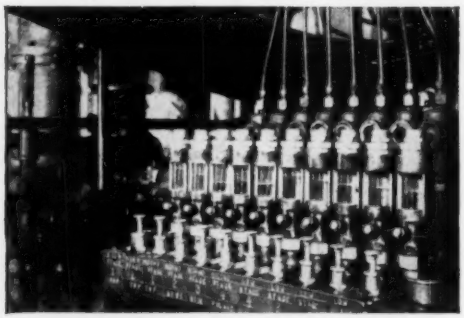
Petroleum Electric Power Association

P.O. BOX 35006, DALLAS 35, TEXAS

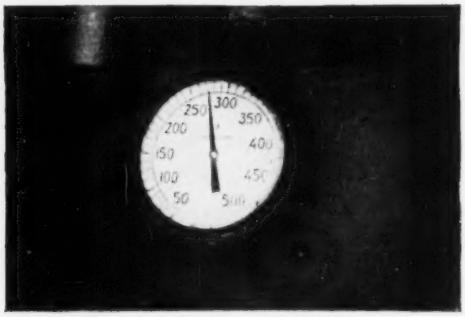
For more data on advertised products, use Readers' Service Cards, last page.



"... Cellulubes were tested for two years in four Cooper Bessemer Air Compressors. Cylinder wear was negligible. Deposits normally found in compressor auxiliaries and valves were reduced or eliminated."



"... A conventional lubricator will pump Cellulubes satisfactorily. No obnoxious vapors—does not present a personnel problem in terms of handling a toxic material."



"... No pressure surges nor evidence of fire in the air accumulator when Cellulubes are used. They are excellent lubricants, and also are effective as detergents."

CELANESE CORPORATION OF AMERICA, CHEMICAL DIVISION
DEPT. 574-E, 180 MADISON AVENUE, NEW YORK 16, N. Y.

Please send me:

☐ Technical bulletin ☐ Sample of_____viscosity.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

Application I have in mind_____

From a trial file covering two years testing in Cooper Bessemer 3-stage air compressors

"NO PRESSURE SURGES...NO EVIDENCE OF FIRE... EXCELLENT LUBRICATION...WHEN FIRE-RESISTANT CELANESE CELLULUBES ARE USED!"

"Cellulube has now been in four of our Cooper Bessemer air compressors for approximately two years. The compressors were inspected during a recent Catalytic Reformer General Inspection. Cylinder liner wear was negligible, particularly when compared to the amount of wear we had experienced when previously using a synthetic lubricant. Cellulube, in addition to acting as a lubricant, is also effective as a detergent. Compressor cylinder air passages which had been heavily coated with carbonaceous materials and deposits laid down by the previous synthetic lubricant, are gradually being removed and the compressors again show the original factory finish. Deposits on valve cages and plates have been reduced and are no longer a problem.

"Cellulube does not present a personnel problem in terms of handling a toxic material. There are no obnoxious vapors from Cellulube. A conventional lubricator will pump Cellulube satisfactorily.

"There have been no pressure surges nor evidence of fire in the air accumulator.

"We believe this material is an excellent lubricant plus the fact that acting as a detergent the deposits normally found in compressor auxiliaries and valves have been reduced or eliminated."

These results are typical of what you can expect from Celanese Cellulubes. They have been developed to meet the pressing need for fire-resistant lubricants which virtually eliminate the problem of carbon deposits.

Celanese Cellulubes are available in 6 controlled viscosities: 90, 150, 220, 300, 550, 1000, S.U.S. @ 100° F. These straight phosphate esters provide excellent lubricity, are non-corrosive and non-reactive.

Celanese Cellulubes open new areas for in-plant protection against fire and explosion. Evaluate them in your own operation. Use coupon to request samples and technical data.

Celanese®
Cellulube®

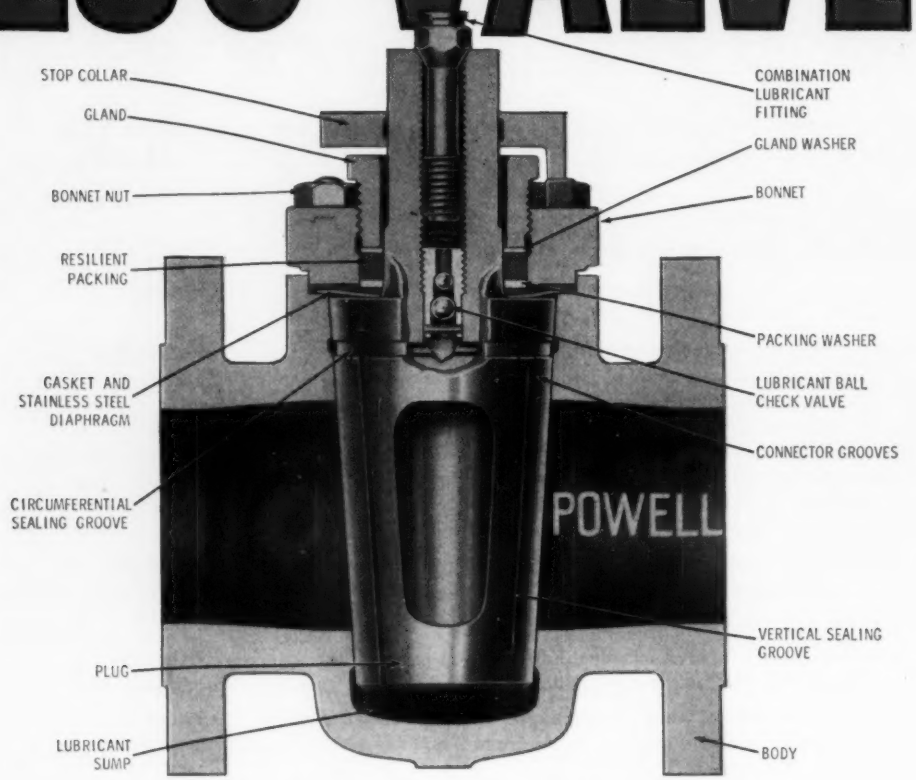
Celanese
CHEMICALS

Celanese Corporation of America, Chemical Division, 180 Madison Avenue, New York 16, N.Y.
In Canada: Canadian Chemical Co., Limited, 2035 Guy Street, Montreal, P. Q., Canada.
Export Sales: Amcel Co., Inc., and Pan Amcel Co., Inc., 180 Madison Avenue, New York 16, N.Y.

CELANESE CELLULUBES

POWELL

LUBRICATED PLUG VALVES



Sectional view Powell Screwed Gland Lubricated Plug Valve.

Like all Powell Valves, Powell Lubricated Plug Valves are superior in their field . . . and have many advantages over other conventional types of Valves.

- Simple design: only three basic parts—Body, Bonnet, Plug.
- Quick, complete shut-off—a quarter turn will close or open the valve.
- Tapered Plug assures positive seating.
- Machined surfaces of plug and body are not exposed in the open position. Any media adhering to the plug when in the closed position is removed when plug is rotated.
- Cavity-free straight passage assures streamlined flow in either direction. Scale and sediment cannot collect.

Powell Lubricated Plug Valves are available in sizes ½" through 16", depending on the type required—Semi-steel 175 and 200 pounds WOG;—Carbon Steel ASA 150 and 300 pounds.

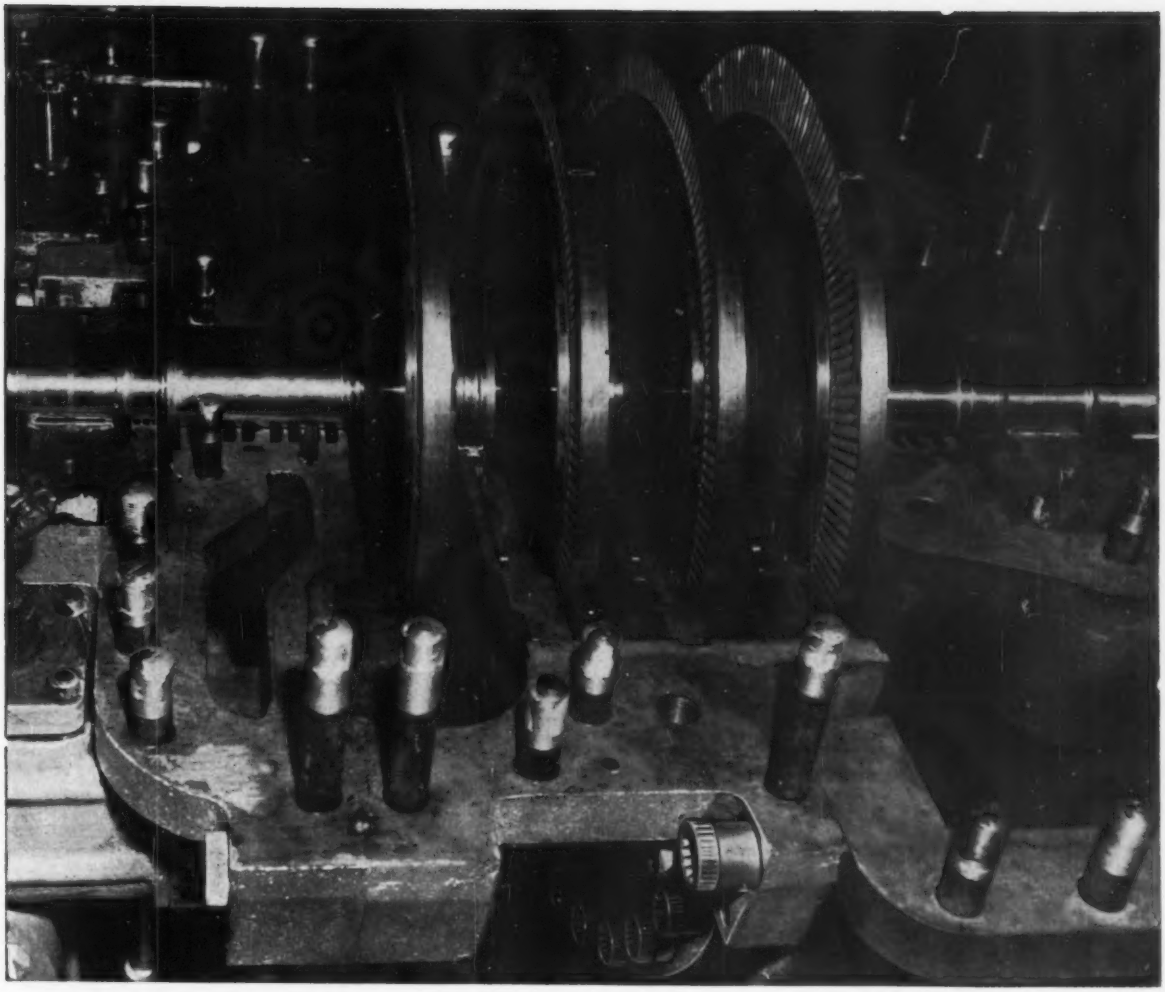
Powell can also furnish Lubricated Plug Valves in other alloys on special order.

For all your valve needs, make it a policy to consult your local Powell Distributor—or write directly to us.

THE WM. POWELL COMPANY

Dependable Valves Since 1846 • Cincinnati 22, Ohio

For more data on advertised products, use Readers' Service Cards, last page.



THE INSIDE STORY OF A MURRAY HIGH SPEED COMPRESSOR

DRIVE TURBINE REVEALS THE REASONS FOR MURRAY'S UNIVERSAL ACCEPTANCE

A look at MURRAY'S rugged construction from the inside shows the husky shaft and heavy accurately formed discs with generous sized hubs designed to withstand the axial and radial stresses imposed by this type of service.

Large-dimension disc rims receive the specially contoured stainless steel blades with the Murray integral shroud. This insures smooth steam passages with maximum strength.

Short bearing spans insure smooth operation and eliminate the hazard of operating in critical speeds.

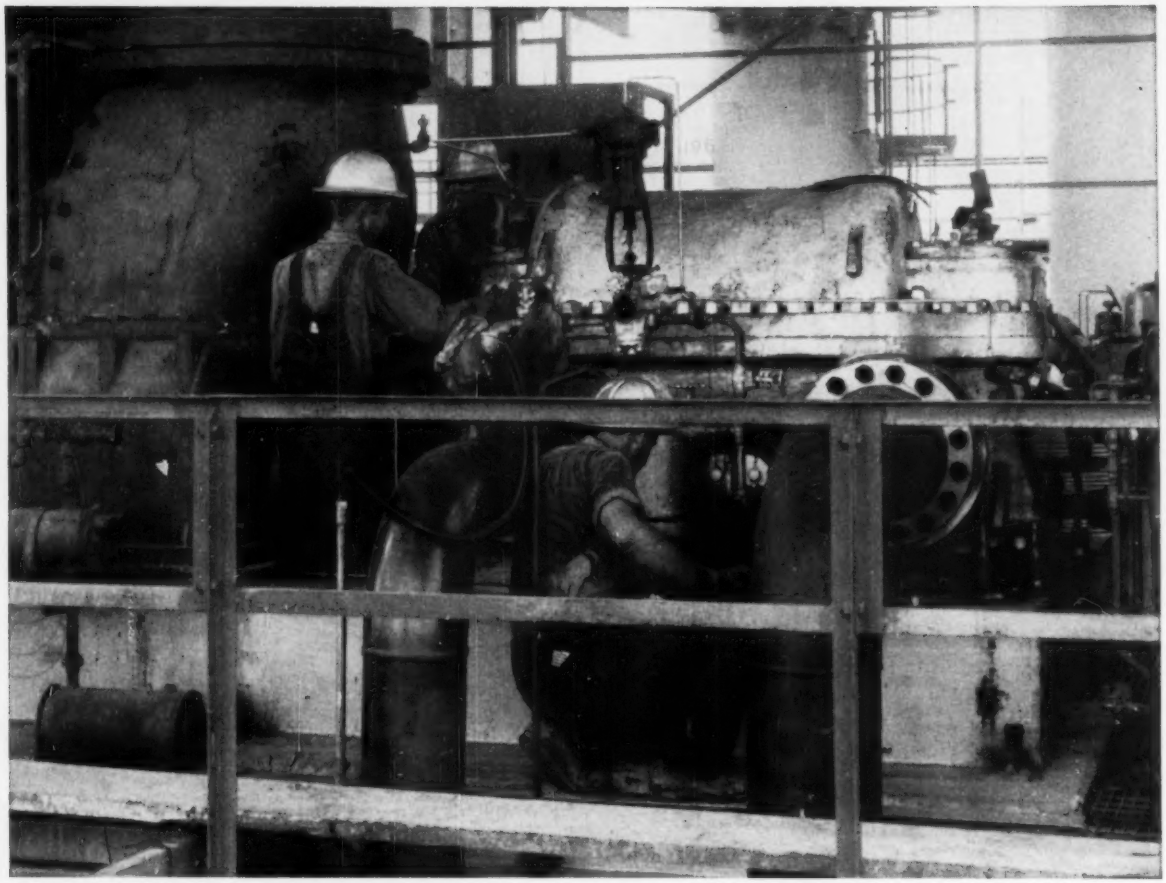
A look at the heavy flanges and husky bolting in the actual unretouched shop photo shown above bears out the extreme ruggedness that typifies every feature of Murray construction.

Our nearest representative will gladly help you solve your high speed compressor drive turbine requirements. Just write to Murray Iron Works Company, Burlington, Iowa, for his name.

Murray
TURBINES

MURRAY IRON WORKS COMPANY • BURLINGTON, IOWA
Builders of Steam Power Equipment for Nearly a Century

For more data on advertised products, use Readers' Service Cards, last page.



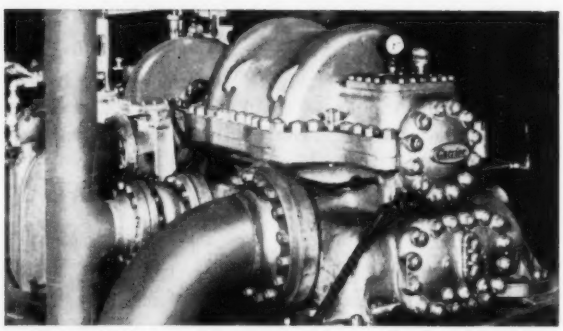
Ethylene compressor being installed at refinery of leading oil company for operation at 600 psi, as low as −185° F. Compressor halves are cast from 4½% nickel steel to resist low temperature impact.

New ethylene compressor works at −185°F ...it's made of cast 4½% nickel alloy steel

Temperatures down to −185°F . . . pressures up to 600 pounds per square inch . . . mean greater efficiency for this ethylene compressor. But these extreme operating conditions increase the danger of low temperature embrittlement. To protect the compressor against cracking, Carrier Corporation of Syracuse, N. Y., specifies cover and base in 4½% Nickel, low carbon steel . . . an alloy with remarkable impact strength at "deep frozen" temperatures.

For the compressor impeller, designers specified heat-treated 2340, 3½% nickel alloy steel. This forged steel, too, provides strength and toughness at low temperature.

Where low temperature puts special emphasis on shock resistance in your process equipment, it will pay you to check the advantages of cast or wrought nickel alloy steels.



Closeup of #350 Carrier compressor, similar to unit shown above. 4½% nickel steel cast upper half weighs 4200 lb, lower half, 5800 lb.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

For more data on advertised products, use Readers' Service Cards, last page.

FOR CATALYTIC REFORMING

4 B&W Refractory Castables

with low iron content

B&W Kaocast

Ten years ago, B&W introduced this 3000° castable which offers a combination of high temperature use limit, as well as very low iron content. B&W Kaocast can either be gunned or cast in place.

B&W Kaocrete-LI

After two years of extensive field service, B&W adds Kaocrete-LI to low iron content castables. B&W Kaocrete-LI, which has an iron content of less than 1%, has exceptionally high strength for resistance against abrasion and erosion. It has sufficient refractoriness for use at temperatures to 2700 F. Suitable for both gunning and casting.

B&W Kaolite-LI

Another new castable with over two years of field service, B&W Kaolite-LI has high insulating properties due to its light weight (only 59 pounds per cubic foot). Its iron content is also less than 1%. It is designed to be applied with a cement gun only. Installation and maintenance time can be cut since Kaolite-LI does not require water curing and heat can be applied directly after gunning.

B&W Kaocrete-32

Developed for special high temperature service, B&W Kaocrete-32 has extremely high strength and a use limit of 3200 F. It can be poured, plastered or gunned into place.

Properties of B&W Low Iron Content Castables

		B&W Kaocast	B&W Kaocrete LI	B&W Kaolite LI	B&W Kaocrete 32
Use limit, °F		3000	2700	2300	3200
Melting point, °F		3200	3100	2700	3297
Average density lb/cu ft after firing		126	131	59	134
Average % Fe_2O_3		1.0	0.9	0.8	1.0
Cold crushing strength—psi average—after heating for 5 hrs. at:	1000 F	700	2500	350	1000
	1500 F	500	2500	350	800
	2000 F	400	1200	300	750
	2200 F	500	1300	450	1000
	2400 F	500	1600	—	2000
	2600 F	1000	6000	—	3000
	2800 F	2200	—	—	3500
	3000 F	3500	—	—	4000
	3200 F	—	—	—	5000
Permanent linear shrinkage—average % less than—after heating for 5 hrs. at:	1000 F	0.3	0.2	0.3	0.2
	1500 F	0.3	0.2	0.4	0.2
	2000 F	0.5	0.2	0.4	0.2
	2200 F	0.5	0.2	0.6	0.4
	2400 F	0.5	+0.1	—	0.5
	2600 F	0.5	—	—	0.5
	2800 F	0.5	—	—	0.5
	3000 F	0.3	—	—	0.2
	3200 F	—	—	—	0.1

Consult your B&W Representative for additional information on these and other B&W Refractories for the refining industry.

B&W REFRACTORIES PRODUCTS: B&W Allmul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics and Mortars • B&W Silicon Carbide

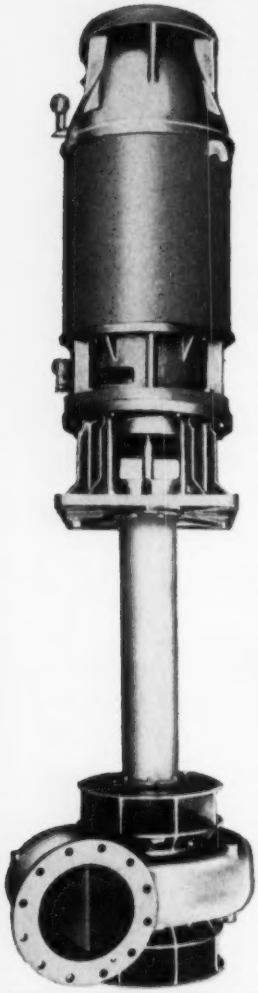
BABCOCK & WILCOX

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
GENERAL OFFICES: 161 EAST 42nd ST., NEW YORK 17, N.Y.
WORKS: AUGUSTA, GA.

Bingham

TYPE "VS" DOUBLE SUCTION DOUBLE VOLUTE VERTICAL PUMP

REDUCES COSTS WITH SHALLOW PIT LOWER MAINTENANCE



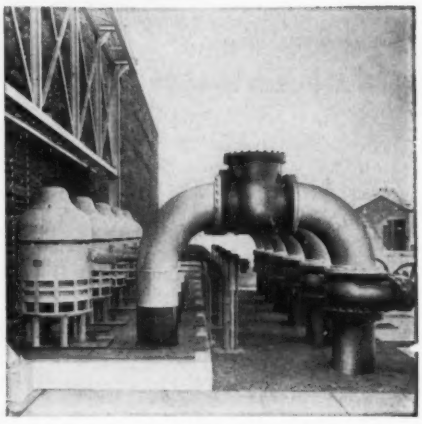
SPECIALLY DESIGNED FOR WET-PIT SERVICES. COOLING TOWER, SPRAY POND, DISPOSAL SUMP, WATER SUPPLY, DRAINAGE — AND OTHER HIGH-CAPACITY, MEDIUM-HEAD WET-PIT SERVICES.

The BINGHAM "VS" Pump, which is an advanced design of a "Double Volute"—"Double Suction" single stage pump, saves money in three ways: (1) Lower installed cost because it does not require a deep pit and can use standard motors. (2) Lower operating cost, because it operates at higher efficiencies, uses less power. (3) Lower maintenance cost, because there is no stuffingbox, all bearing loads are light, and the installation is easy to inspect and service.

The "Double Volute" construction of the "VS" Pump maintains radial balance of its rotating element throughout the entire operating range of the pump. Wear due to "Side Push" is eliminated.

The "Double Suction" feature of this pump eliminates axial hydraulic thrust, thereby permitting the use of standard vertical motors.

These and many other important reasons make the BINGHAM "VS" Pump the most logical choice today for wet pit service. For full details call your nearest Bingham Office or write for Bulletin No. 110.

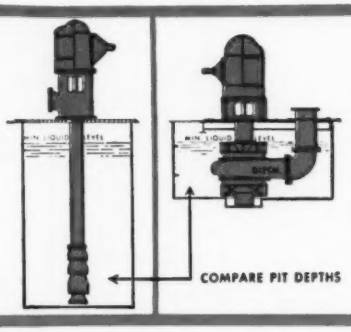


A Battery of Bingham "VS" Pumps Operating at a major Gulf Coast gas processing plant.

COMPARE THESE PITS FOR COST

OLD

Conventional Deep-Well Turbine Pump Installation . . . requires the pit be deep enough to maintain sufficient pumpage above the pumping element in order to provide the required NPSH.



NEW

Bingham "VS" Pump Installation . . . requires only a shallow pit and only sufficient pumpage to cover the pumping elements. Pit construction is thereby *greatly reduced.*

Bingham SINCE 1921

DOUBLE VOLUTE PUMPS RADIAL BALANCE

BINGHAM PUMP COMPANY

General Offices: **2800 N.W. Front Avenue, Portland 10, Oregon**

Factories: **Portland, Ore. • Vancouver, B. C., Canada**

SALES AND SERVICE OFFICES

BOSTON, MASS.
CHICAGO, ILL.
CLEVELAND, OHIO
DALLAS, TEXAS
DENVER, COLO.
HOUSTON, TEXAS
KANSAS CITY, MO.
LOS ANGELES, CALIF.
NEW ORLEANS, LA.
NEW YORK CITY, N.Y.
PHILADELPHIA, PA.
PITTSBURGH, PA.
SAN FRANCISCO, CALIF.
SEATTLE, WASH.
ST. LOUIS, MO.
ST. PAUL, MINN.
TULSA, OKLA.
TORONTO, ONT., CAN.
VANCOUVER, B. C., CAN.

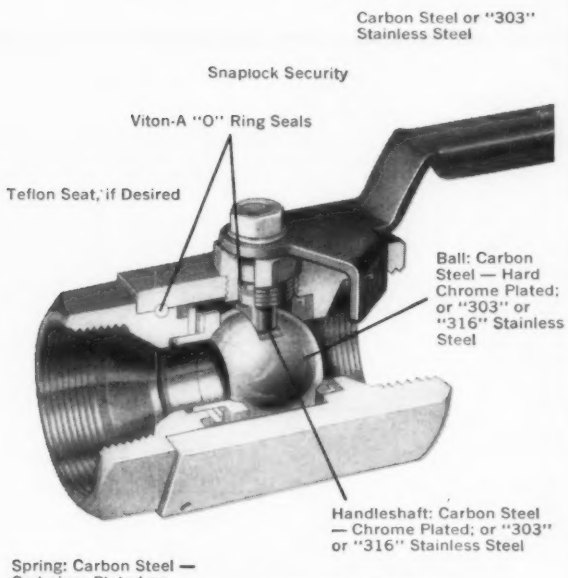
For more data on advertised products, use Readers' Service Cards, last page.

Rockwood Ball Valves

Secure in seconds...

Snaplock Type

(now available with Viton-A trim)


Carbon Steel or "303" Stainless Steel
Snaplock Security
Viton-A "O" Ring Seals
Teflon Seat, if Desired
Ball: Carbon Steel — Hard Chrome Plated; or "303" or "316" Stainless Steel
Handleshaft: Carbon Steel — Chrome Plated; or "303" or "316" Stainless Steel
Spring: Carbon Steel — Cadmium Plated or "410" Stainless Steel
Corrugated spring holds free floating ball on seat . . . compensates for wear . . . cuts maintenance

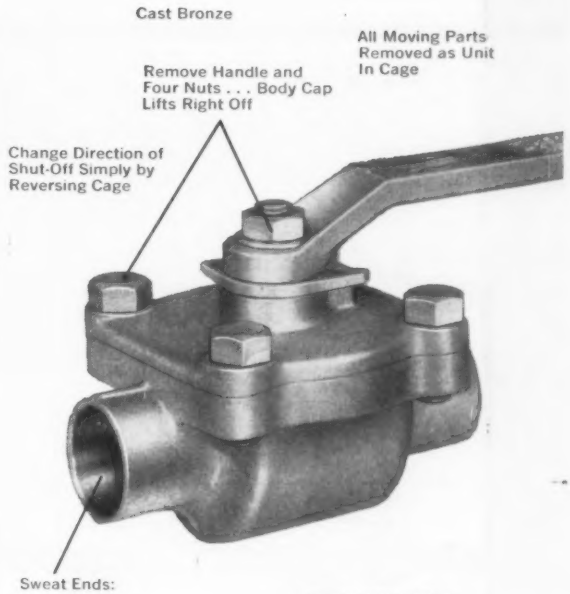
300 p.s.i. — W.O.G.

Sizes: ¼" thru 2"

Securely locked — cannot be accidentally opened or closed.

Serviced in minutes...

Top Entry Type


Cast Bronze
All Moving Parts Removed as Unit In Cage
Remove Handle and Four Nuts . . . Body Cap Lifts Right Off
Change Direction of Shut-Off Simply by Reversing Cage
Sweat Ends: ½", ¾", and 1"
Rugged Stem Keys Directly into Floating Ball

300 p.s.i. — W.O.G.

Sizes: ½", ¾", 1" and 2½"

Buna N Seals; Forged Hard Chrome Plated Ball; Beryllium Copper Spring; Buna N Seats (also available in Teflon, nylon, and Viton-A)

Whether it's positive security against accidental operation you're looking for or extra-easy servicing, you'll find the valve that fills your exact needs in the Rockwood line. And — you'll get all the Rockwood extra-performance features such as: ¼ turn opening and closing, 8-position lever operation, plus that smooth, full, round flow. Mail coupon for complete specifications.

Tested and listed by Underwriters' Laboratories, Inc.

ROCKWOOD BALL VALVES

FULL, ROUND FLOW

Distributors in all principal industrial areas

ROCKWOOD SPRINKLER COMPANY
1031 Harlow Street
Worcester 5, Massachusetts

Please send details on ☐ Rockwood Snaplock Valves ☐ Rockwood Top Entry Valves.

Name .....

Title .....

Company .....

City ..... *Zone* ..... *State* .....

For more data on advertised products, use Readers' Service Cards, last page.

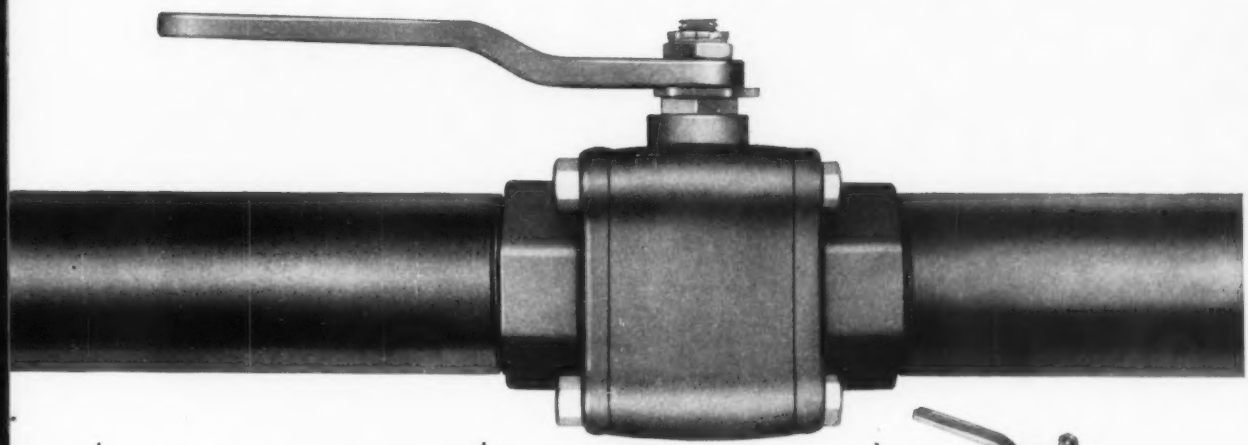
COMPARE . . .

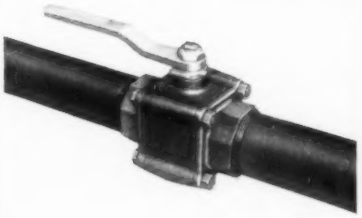
	ECON-O-MISER	GATE VALVE	FLANGED GATE VALVE	DIAPHRAGM VALVE	LUBRICATED PLUG VALVE
FLOW CHARACTERISTICS	Smooth round flow	Turbulence results in excessive pressure drop	Turbulence results in excessive pressure drop	Turbulence results in unusually high pressure drop	Constricted flow . . . pressure drop
METHOD OF CLOSURE	CLOSED ¼ turn operation OPEN	2½ to 3½ turns of hand wheel	2½ to 7 turns of hand wheel	2½ to 3½ turns of hand wheel	¼ turn operation
MAINTENANCE CHARACTERISTICS	Seats and "O" Rings easily replaced	Valve normally thrown away	30% to 50% of purchase price	In-line maintenance possible	Regular lubrication necessary to maintain seal
SIZE (PIPE SIZE)	CENTER TO TOP—OPEN 3 5/16	12 1/8	16 1/2	7 1/4	10 1/2
LIFE EXPECTANCY	Half million cycles not unusual	Metal-to-metal seating limits life	Metal-to-metal seating limits life	Better than gate valve	Very good if lubricated regularly

THE ECON-O-MISER BALL VALVE IS THE IDEAL REPLACEMENT FOR MOST ON-OFF VALVES NOW IN USE IN THE PROCESS INDUSTRIES!

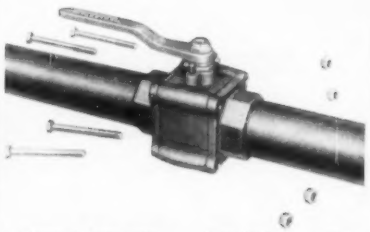
MORE EFFICIENT . . . LESS COSTLY

THE ECON-O-MISER BALL VALVE





Compact, efficient ECON-O-MISER Ball Valves are today's smoothest operating on-off valves. A quarter turn of the handle allows full operation and you can tell at a glance whether the valve is open or closed. More . . . ECON-O-MISER Ball Valves act as both valve and union . . . eliminate costly inventory and labor. Minimum turbulence and greater economy make this valve ideal for hundreds of applications.



Remove four nuts . . . four bolts . . . and the entire center section lifts out for servicing. Quick, convenient maintenance saves money **and** this unique design means pipe ends never have to be removed from the line. Seating surfaces and O-Rings are easily replaced . . . whole valve back in operation in minutes. Reduces inventory expenses and frees maintenance personnel from time consuming repairs.

The ECON-O-MISER Ball Valve is available in many combinations of seats, O-Rings and body materials. Almost any media can be handled by the ECON-O-MISER and sizes range from ¼" through 6". Made of bronze, aluminum, carbon steel, stainless steel or aluminum bronze. We'll be happy to furnish information or application data.

THE ONLY VALVE IN INDUSTRY THAT SERVES AS BOTH VALVE AND UNION!

Complete, technical information in new "Comparison" bulletin.

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☐ Please forward bulletin EB 101. ☐ Please ask sales engineer to call for appointment. ☐ Send information on ECON-O-MISER FLANGE BALL VALVE.

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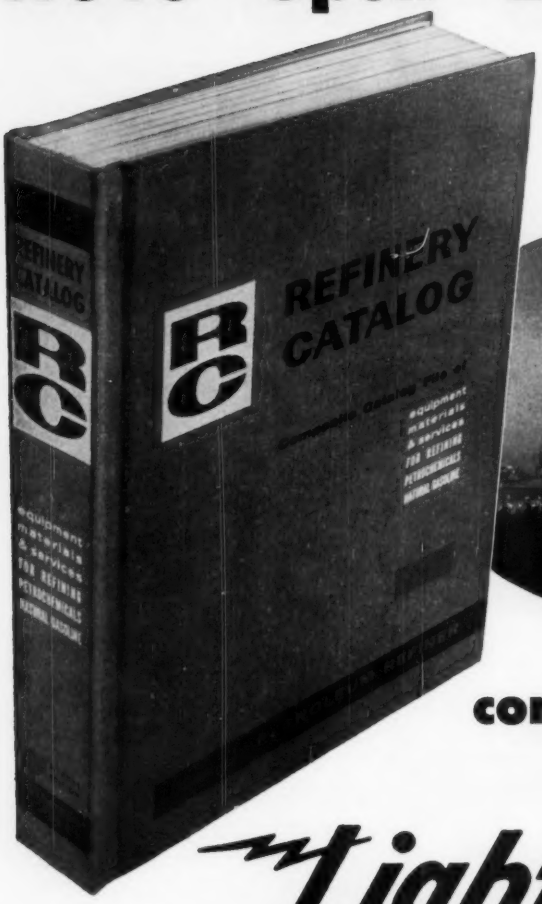
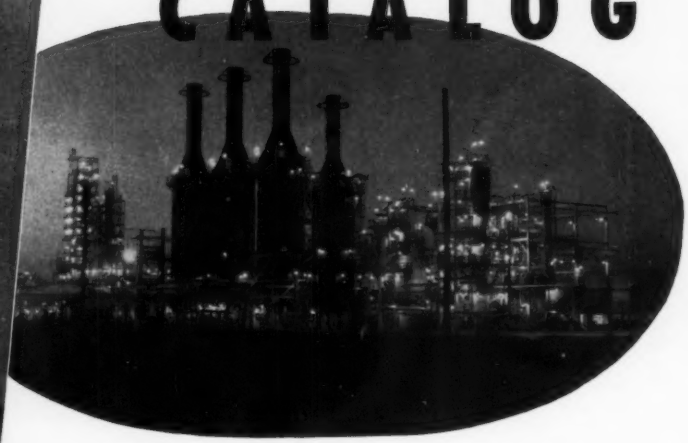
We're "Open" 24 Hours a Day in



REFINERY CATALOG



complete, quick reference information on

Lightnin® Mixers

The pages of REFINERY CATALOG are never closed . . . bringing you around the clock information on products and services. Because we know you prefer such a single-source reference, we have selected this Catalog to carry our catalog data to more than 8,500 buyers and specifiers in the refining, petrochemical and natural gasoline industry throughout the world. We believe this pre-filed data will be of time-saving value and convenience to you.

When you want quick facts on fluid mixing, turn to the catalog data in Refinery Catalog. There you'll find condensed catalog information on LIGHTNIN Mixers for any type of service. The LIGHTNIN catalog unit is made up of 16 fact-filled pages on mixer construction, impeller selection, scale-up, and mixer efficiency. If you can't find all the information you need, check the list of LIGHTNIN sales representatives and call the nearest one.

MIXING EQUIPMENT Co., Inc. 164 Mt. Read Blvd., Rochester 3, N. Y.

IN CANADA: Greey Mixing Equipment Ltd., 100 Miranda Ave., Toronto 19, Ontario

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BREAKTHROUGH

in oxygen measurement!

Now you can measure oxygen concentration simply, quickly, accurately with this new direct meter reading instrument from MSA.

The M-S-A® Portable Oxygen Indicator puts the finger on oxygen deficiency and hazardous oxygen leakage. In purging gas transmission lines or process systems of air, this precision instrument can be used to determine rate of progress.

You can also use it to do a number of other jobs that could never be done in the past. Take spot checks of inert atmospheres. Solve problems of combustion control. Measure oxygen content of flue gases. Guide the proper proportion of fuel and air.

The M-S-A Portable Oxygen Indicator measures oxygen in *gaseous mixtures* at location of sampling line inlet, at time of tests. Simplicity of design makes it easy to operate, convenient to use, and a snap to service. Large meter scale can be read at a glance. 0.5% accuracy.

An accessory liquid trap guards against condensation of water vapor from high temperature samples. An accessory scrubber containing chemisorbent is available to guard against strongly acid gases. Entire instrument is housed in rugged aluminum case only 6¾" x 4⅛" by 5¾" high. Sampling lines of various lengths are available. Weighs only 5¾ lbs.

The versatility of such an instrument could add a big boost to the efficiency of your operation. Another consideration is the extra margin of safety it provides for work crews. Ask the MSA Representative for a demonstration, and write MSA for a descriptive bulletin.

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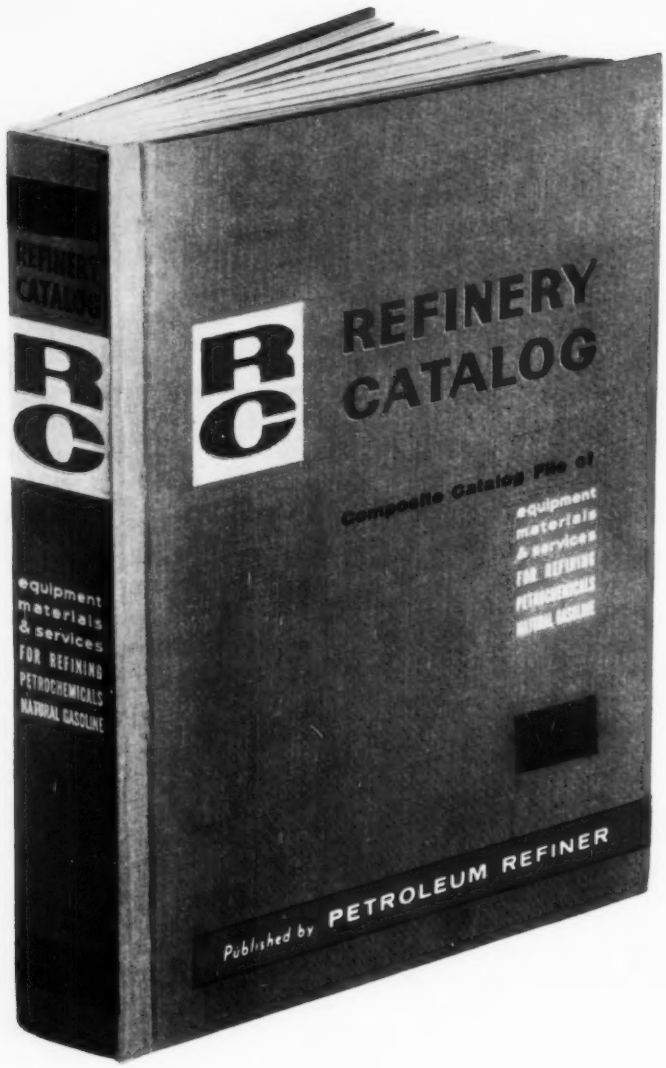
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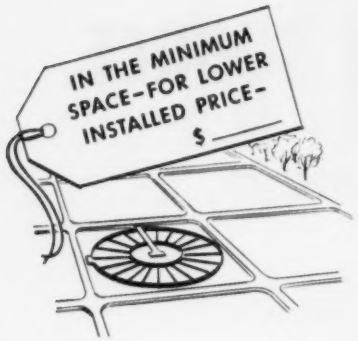
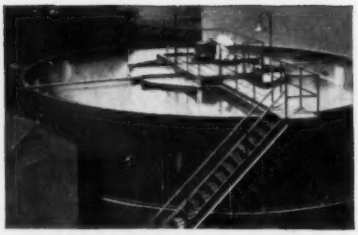
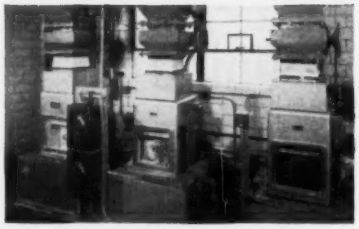
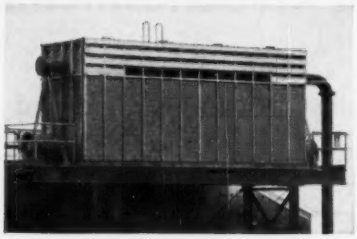
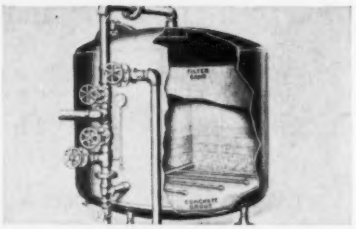


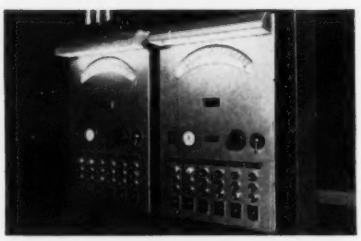
You get dependable performance for all types of brine and water treatment with INFILCO equipment











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plants for clarification, softening and stabilization

Effective mixing of chemicals and raw water with recirculating slurry and downflow separation effect better treatment in minimum area — and at low cost. For water, brine or waste treatment. BULLETIN 1825

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Accurately controlled feed rates and maximum economy

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AERATORS and DEGASIFIERS

For all types of gas-liquid transfer applications. Efficient oxidation, carbon dioxide and hydrogen sulfide removal. BULLETIN 106

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MODERN INSTRUMENTATION

Maintains efficiency, reduces operating cost of treatment

Design and assembly of pneumatic, electric or hydraulic control components for manual or automatic, constant or variable rate plants. Operating consoles and control panels specifically engineered for complete treating plants. BULLETIN 1100

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INFILCO CAN help you solve any water and brine treatment problem in oil production and refining

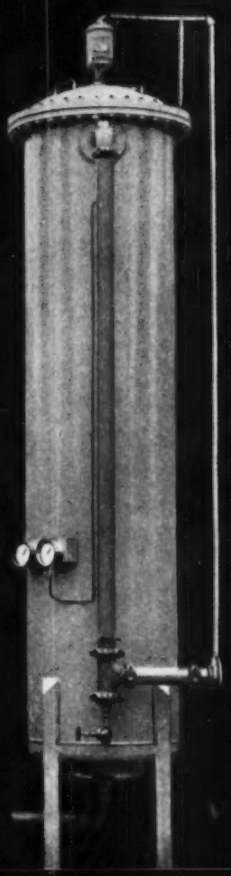
From experience, extending over 60 years, INFILCO can give you the best results with lowest *first* cost and *operating* costs.

No other line of equipment is so complete—none so advanced in method and design. Above are a few examples.

It will pay you to investigate. Inquiries are invited on all matters relating to water or brine treatment. Write today for new condensed catalog, Bulletin 80, for a more complete description of INFILCO products.

THE ONLY COMPANY impartially offering equipment for ALL types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

GIVE YOUR NATURAL GAS DRYING COLUMN A FIVE-FOLD BOOST!



More than two years of field service prove it—LINDE Molecular Sieves have five times the drying capacity of silica and alumina—are the most economical desiccants you can use for natural gas drying;

- Molecular Sieves have water capacities in the range of 10% to 15% by weight. This compares with 2% to 3% when drying pipeline gas—and 5% to 8% when drying field gas—with silica and alumina type desiccants.
- Molecular Sieves reduce effluent water concentrations three-fold.

The high capacity of Molecular Sieves in your present equipment will allow you to increase throughput without the expense of new drying towers.

Besides solving your drying problems, Molecular Sieves will also sweeten your natural gas stream—you get a single desiccant system that removes all three impurities—water, hydrogen sulphide, and mercaptans.

For further information on LINDE Molecular Sieves, contact your nearest LINDE office or write Linde Company, 30 East 42nd Street, New York 17, N. Y. *In Canada:* Linde Company, Division of Union Carbide Canada Limited. Address Dept. PR-5.

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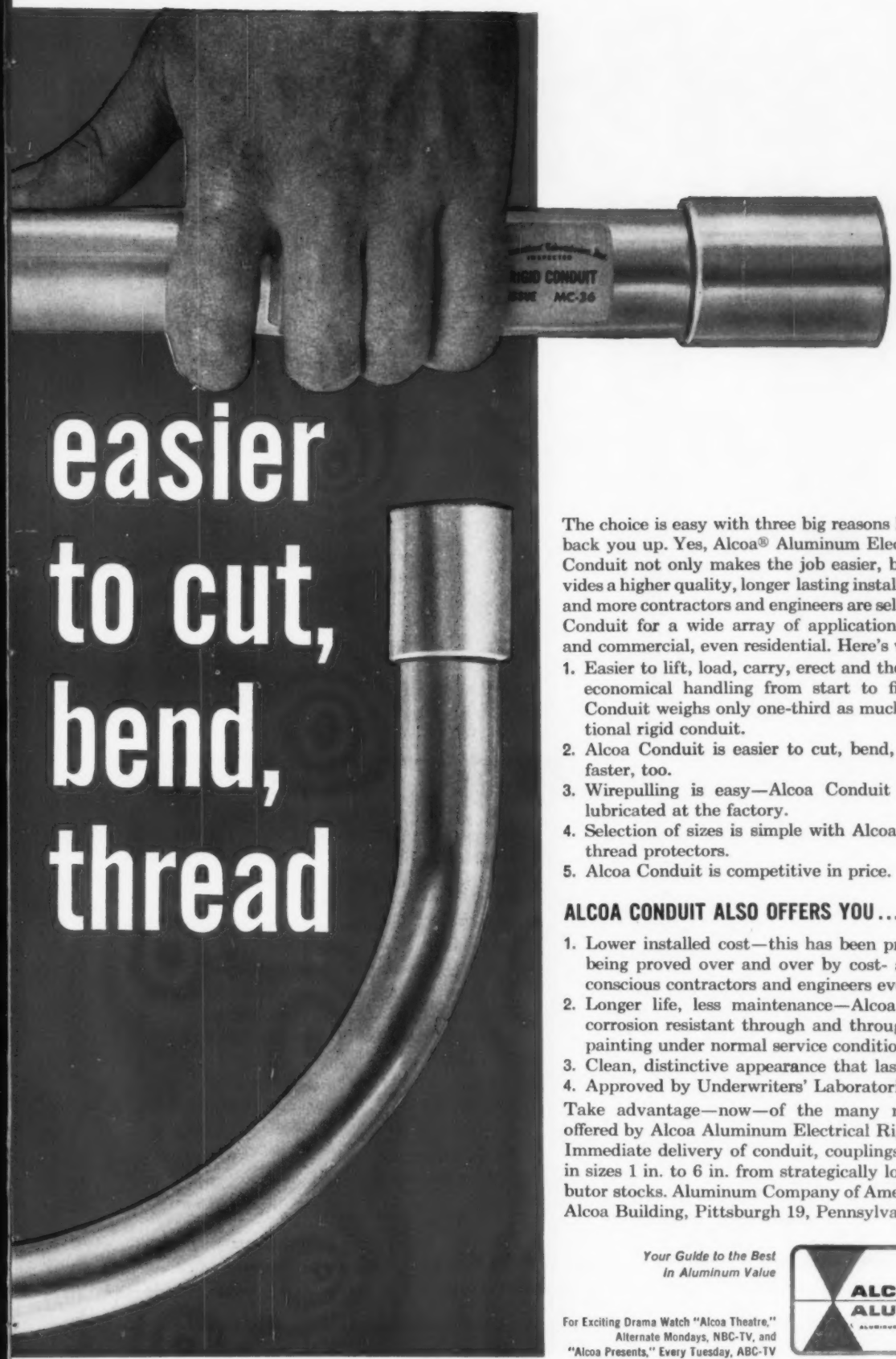
ALCOA ALUMINUM CONDUIT...

easier to handle,

easier to install,



easier to cut, bend, thread

The choice is easy with three big reasons like these to back you up. Yes, Alcoa® Aluminum Electrical Rigid Conduit not only makes the job easier, but also provides a higher quality, longer lasting installation. More and more contractors and engineers are selecting Alcoa Conduit for a wide array of applications, industrial and commercial, even residential. Here's why:

1. Easier to lift, load, carry, erect and therefore more economical handling from start to finish—Alcoa Conduit weighs only one-third as much as conventional rigid conduit.
2. Alcoa Conduit is easier to cut, bend, thread . . . faster, too.
3. Wirepulling is easy—Alcoa Conduit is specially lubricated at the factory.
4. Selection of sizes is simple with Alcoa color-coded thread protectors.
5. Alcoa Conduit is competitive in price.

ALCOA CONDUIT ALSO OFFERS YOU...

1. Lower installed cost—this has been proved . . . is being proved over and over by cost- and quality-conscious contractors and engineers everywhere.
2. Longer life, less maintenance—Alcoa Conduit is corrosion resistant through and through, needs no painting under normal service conditions.
3. Clean, distinctive appearance that lasts and lasts.
4. Approved by Underwriters' Laboratories, Inc.

Take advantage—now—of the many new benefits offered by Alcoa Aluminum Electrical Rigid Conduit. Immediate delivery of conduit, couplings and elbows in sizes 1 in. to 6 in. from strategically located distributor stocks. Aluminum Company of America, 2144-E Alcoa Building, Pittsburgh 19, Pennsylvania.

Your Guide to the Best In Aluminum Value

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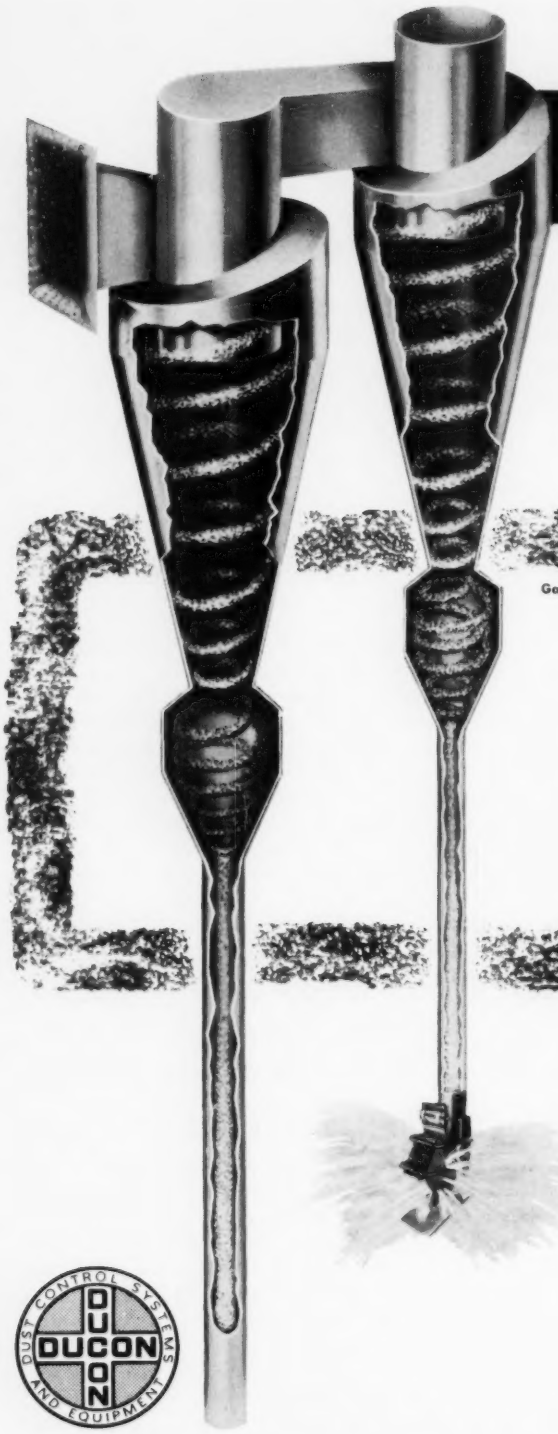
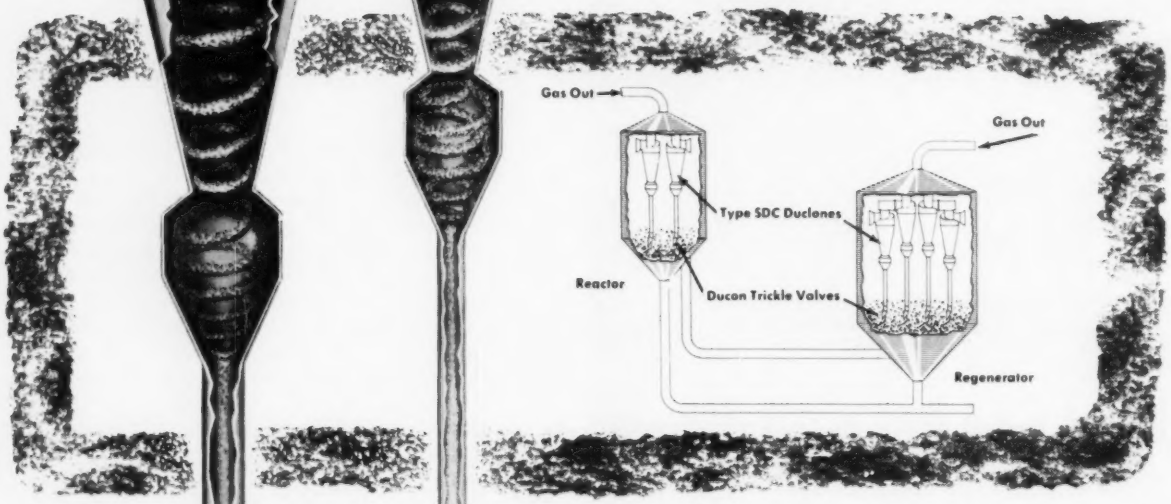


. . . in catalyst recovery

Type *SDC* DUCLONES assure

- *HIGH EFFICIENCY*
- *LOW PRESSURE LOSS*
- *LONG SERVICE LIFE*



Ducon Type SDC Catalyst Recovery Duclones have earned the approval of the world's leading refineries for their effectiveness in catalyst recovery and other fluid bed processes.

The exceptional performance of Type SDC Duclones is the result of 6 unique design features:

1. Helical Inlet to reduce turbulence
2. Steep Cone for improved dust separation
3. Dust Trap to reduce entrainment
4. Scroll Outlet to provide low resistance, tangential gas exit
5. Small Diameter for high efficiency
6. Vortex Shield to reduce entrainment of dust in the upward flowing gas stream.

For additional information on Type SDC Duclones send for Bulletin C-2058.

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CYCLONES • CENTRIFUGAL WASH COLLECTORS • TUBULAR CLOTH FILTERS • DUST VALVES

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High pressure processing . . . including Hydrogenation

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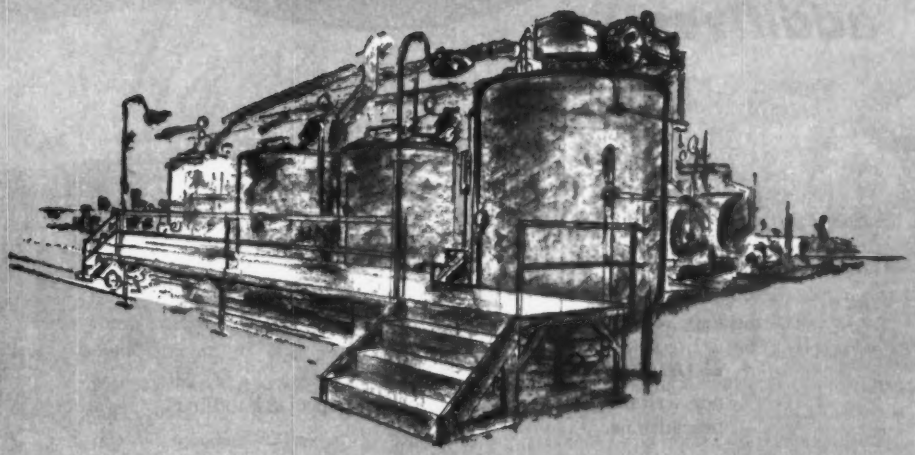

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UOP 88®

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  Prevents gum formation and stabilizes tetraethyl lead.
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  acts as catalyst in air-oxidation of mercaptans.
- ***Completely Non-Toxic***
  non-irritating to the skin, requires no special handling precautions.

A completely new gasoline additive! As an antioxidant, UOP 88 is high in potency and uniform in quality. Too, it is the lowest-cost phenylenediamine type antioxidant on the market. UOP 88 will also fill your need as an air-sweetener for catalytically cracked naphthas. Non-toxic and non-irritating to the skin, it is a 100% active ingredient and remains liquid at all ambient temperatures.

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LEAK-PROOF ONE-PIECE CONSTRUCTION from socket to tip of bourdon tube...accomplished by the exclusive Marsh "Conoweld" process.

STURDY "MARSHALLOY" CASE formed of boiler-plate thickness steel, copper clad inside and outside by "Marshalloy" process to give it all the durability and the corrosion resistance of solid copper with the dependable strength of steel.

SUPERLATIVE "MASTERGAUGE" MOVEMENT with exclusive "coined" sector gear, self lubricating, frictionless action and other refinements that add years to service life.

TYPES FOR EVERY SERVICE...wide range of bourdon tubes including stainless steels and monel. Full range of pressures, vacuum, compound gauges in endless sizes, case styles. Only Marsh has the "Safecase" for dangerous gauge applications.

"Mastergauge" is standard bearer for the broad line of Marsh Gauges fully covered in Catalog 76-G. All are available with the "Recalibrator" —best way to correct a gauge that has been knocked out of adjustment.

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LOW COST

another reason leading refiners use QO® FURFURAL

You get double economy using QO furfural as a selective solvent. First—its initial price is remarkably low. Second—you realize continued savings because you recover virtually all of it for re-use.

Now check these other features . . . more reasons why solvent refining with furfural is profitable

HIGHLY SELECTIVE—QO Furfural is highly selective in separating a wide variety of closely related compounds in such operations as refining of lube oil, gas oil, cycle stock, and extractive distillation of hydrocarbons.

EASILY RECOVERED—Some refiners report solvent losses of the furfural circulated are less than 0.02%.

THERMALLY STABLE—QO Furfural is thermally stable under the conditions of extraction and recovery, thus permitting long continuous plant operation.

READILY AVAILABLE—QO Furfural is readily available in large quantities from annually renewable raw material sources.

Add up the facts—you'll see, as other refiners have, that you're farther ahead with QO furfural.

Write for Bulletin 203-A—"Physical Data on QO Furfural.

The Quaker Oats Company

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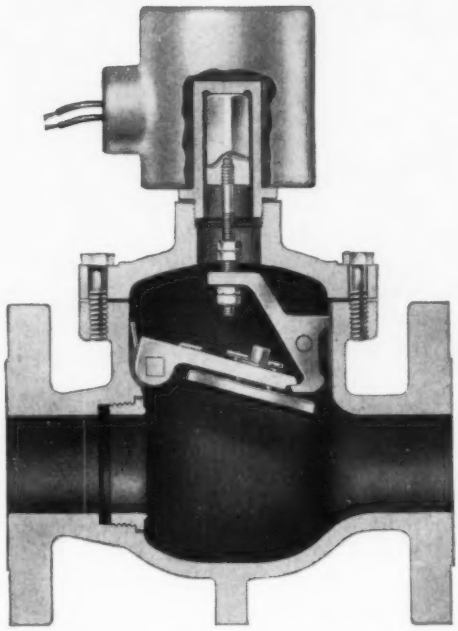
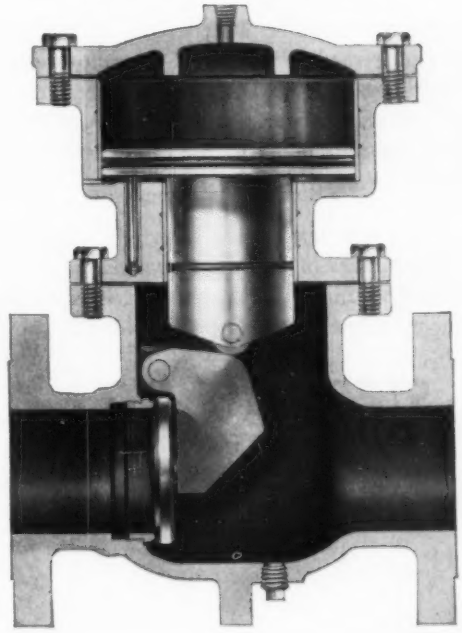
Latch type valve closes instantly



Piston type valve opens instantly



Coppus Sentry® Valves Give Split-Second Action

Coppus Sentry Valves automatically protect property, materials, and processing with their quick, positive action. These are all full-flow valves for use on liquid and gas lines.

The latch-type valves stop flow instantly, automatically. They may be actuated by excess flow, overpressure, underpressure, overtemperature; or by energizing or de-energizing a solenoid.

These valves remain closed until manually reset. They are extremely popular in the chemical, petroleum and gas industry.

The piston type valve opens instantly. Opening and closing of this valve may be from any remote location — either automatically or manually. It is ideal for deluge systems.

Sizes run from 1½" to 8".

To get a more detailed story on this remarkable line of Coppus Sentry Valves, use the coupon to ask for Bulletin 500. Coppus Engineering Corp., Worcester 2, Mass.

ANOTHER COPPUS "BLUE RIBBON" PRODUCT

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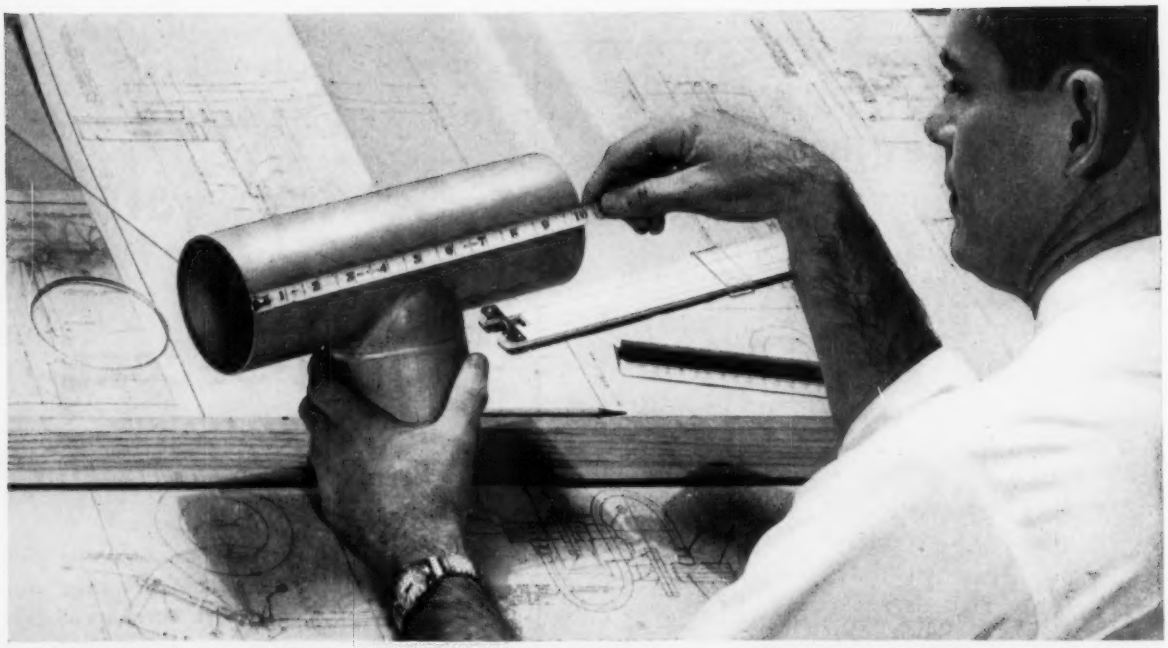
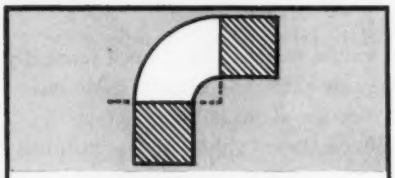


SAVINGS ARE MEASURABLE...START TO FINISH WITH *LONGER LENGTH* SPEEDLINE FITTINGS



HERE'S HOW YOU CAN CUT PIPING COSTS

A conventional 90° elbow is shown inside the dotted line. The shaded areas indicate the extra length you get with a Speedline fitting—at no extra cost. For example, on a 3" Speedline Elbow it means 4" more pipe. Thanks to the longer length of all Speedline fittings, all types of joints are made more easily . . . cost less . . . than with conventional fittings. Make your own comparisons.

For location of Authorized Distributor nearest you, see Speedline listing on page 593 in Chemical Engineering Catalog.

With this 3" Speedline Tee you get 3¼" "*more length*" at no extra cost. Speedline's *tangential feature* cuts costs and design detailing, too . . . lets you select the best joint to meet assembly requirements . . . means more clearance for welding and easier pipe aligning. Flange where you want to, weld where you want to . . . *any* type joint can be used on *any* or *all* ends of a Speedline corrosion resistant fitting!

Greater flexibility of Speedline long length fittings adds up to faster assembly and *lower installed costs*—even for the most complex process piping system. And, of course, Speedline corrosion resistant fittings *cut material costs two ways:* they give *more* pipe length per fitting and they facilitate use of economical *light wall stainless* steel pipe.

Before you plan any new installation or system addition, investigate the many advantages of Speedline's *tangential* feature. Write for Speedline Catalog showing how you save with the complete line of Speedline fittings.

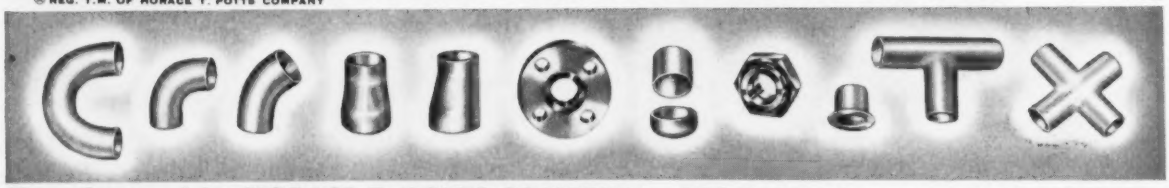
Speedline®

® REG. T.M. OF HORACE T. POTTS COMPANY

STAINLESS STEEL FITTINGS

SPECIALLY DESIGNED FOR SCHEDULES 5 AND 10 PIPE

P-800



Manufactured by HORACE T. POTTS COMPANY • 566 E. Erie Avenue • Phila. (34), Pa.

Here's Why Oil Men Specify
EC&M HIGH VOLTAGE STARTERS

2200-4800 Volts
Totally Oil-Immersed

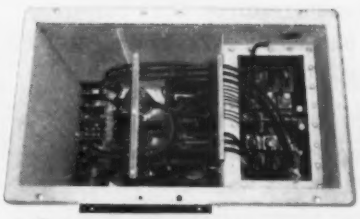
EC&M Type ZHS Starters at Southwestern pipe line trunk station

Designed for Easier Installation, Inspection and Maintenance

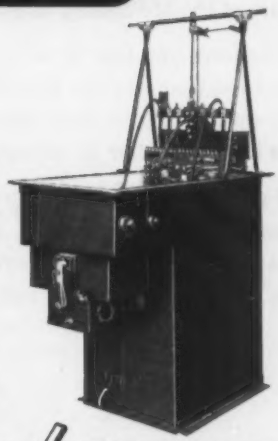
Specifically designed for Class I, Group D, Division 2, semi-hazardous locations . . . NEMA 3R (raintight enclosure). 50,000 KVA interrupting capacity.

***Fast* installation** because starters are shipped with all internal wiring complete. All leads are of anti-syphon construction.

Easy inspection • Contactor and overload relay panel may be raised, as one unit, above oil level. No disconnecting of bolts or leads. *(See lifting mechanism at extreme right.)* Safer, too . . . note view windows on each side of load-break disconnect switch.



View from above shows complete internal wiring . . . anti-syphon leads. These "ready-to-use" starters are complete with control transformer for 220 volt push button operation.



EC&M Contactor lifter raises contactor and overload relay above oil level for easy inspection. No bolts or leads to disconnect.

For literature describing EC&M's complete starter line, write for Bulletin 8131-T

THE ELECTRIC CONTROLLER & MFG. CO.
A DIVISION OF THE SQUARE D COMPANY
CLEVELAND 28 • OHIO

8020

For more data on advertised products, use Readers' Service Cards, last page.

we've made it easy for you to keep your temperature readings accurate

It may take an explosion, or a truck running rampant, to throw an RMC thermometer out of calibration . . . but it does happen sometimes. When it does, you want to get it back on the job in a hurry.

That's why our engineers included an *external* dial reset screw on the back of the RMC industrial thermometer—so that it can be reset instantly without shutting down or closing off a line.

They put quite a few plus features in at the same time. The hermetically tight air seal is not destroyed, because nothing has to be opened or taken apart. They've eliminated the hazard of a twisted shaft by rotating the "dial" instead of the pointer.

This attention to detail in design and manufacture is a part of the life history of every RMC thermometer.

Whenever you look at an RMC thermometer we want you to *know* that you can depend on its readings. Only then do we feel that we have done our job the way we want to do it . . . for after all, accuracy is our business.

If you have any temperature, pressure, or liquid level measuring problems, write, wire or phone. The chances are we have the indicating instrument you want. If we don't, we'll build it for you, or tell you where you can get it.

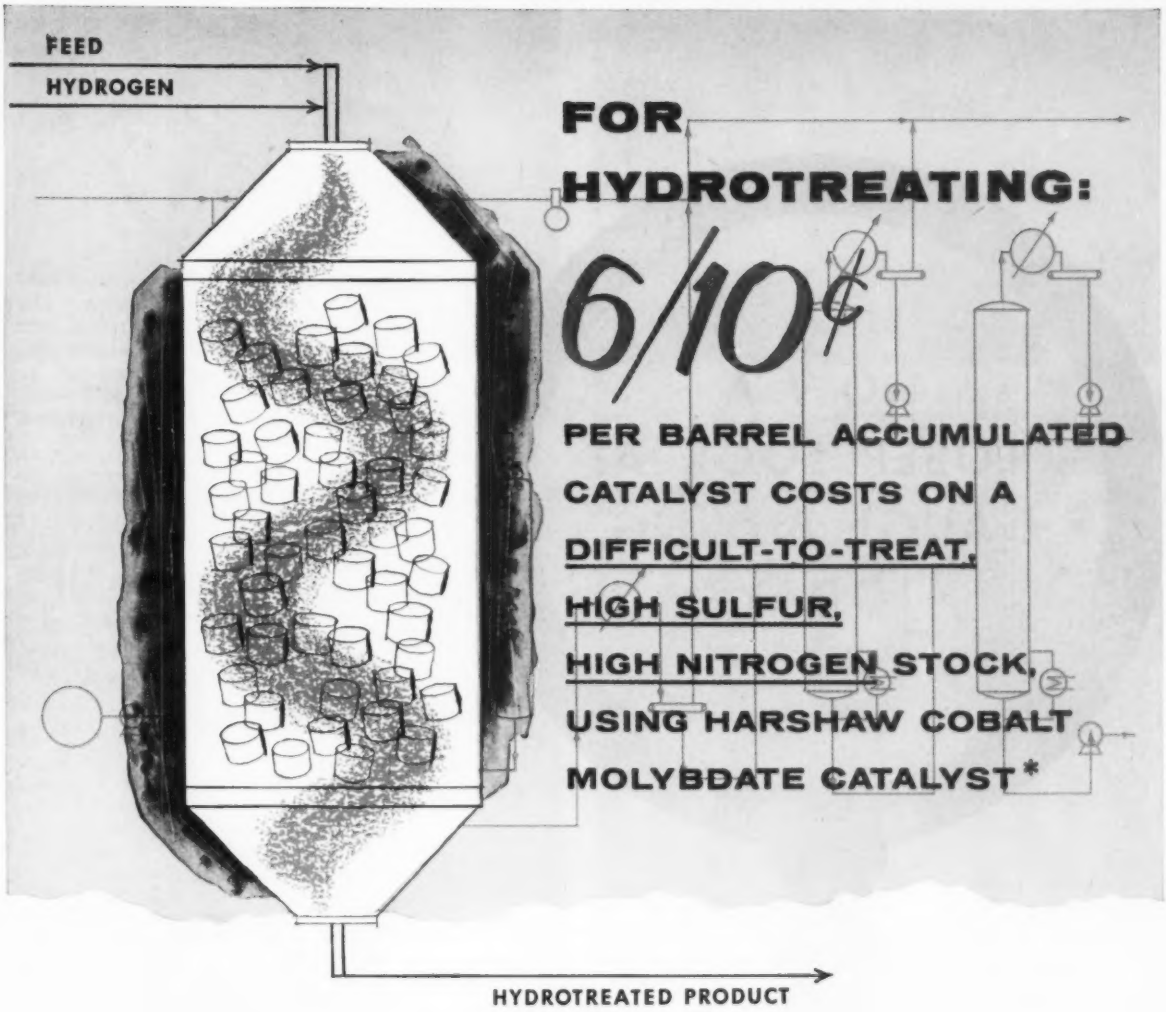
Ralph Foster

RMC

ROCHESTER MANUFACTURING CO., INC.
38 ROCKWOOD STREET • ROCHESTER 10, N.Y.

LIQUID LEVEL, TEMPERATURE AND PRESSURE INSTRUMENTS

Representatives in all Principal Cities



Consistently low catalyst costs for hydrotreating, using Harshaw Cobalt Molybdate Catalyst, are possible because the inherent ruggedness and high thermal stability of our catalyst permits repeated regenerations while maintaining full activity—in one instance *223* regeneration cycles without loss in activity.

This versatile Harshaw catalyst performs efficiently over a wide range of feedstocks—from low boiling naphthas to heavy coker distillates. In all applications, the long life of our catalyst reflects reduced per-barrel costs.

For further information contact the Harshaw Branch nearest you. Our representative will be happy to discuss with you the application of Harshaw Cobalt Molybdate Catalyst to your operation.

*Based on an actual customer experience to date in a specific unit still operating. Its continuing operation will further reduce the 6/10¢ per barrel cost.

HARSHAW

THE HARSHAW CHEMICAL CO.

1945 E. 97th STREET • CLEVELAND 6, OHIO

CHICAGO
CINCINNATI
CLEVELAND
DETROIT
HASTINGS-ON-HUDSON
HOUSTON
LOS ANGELES
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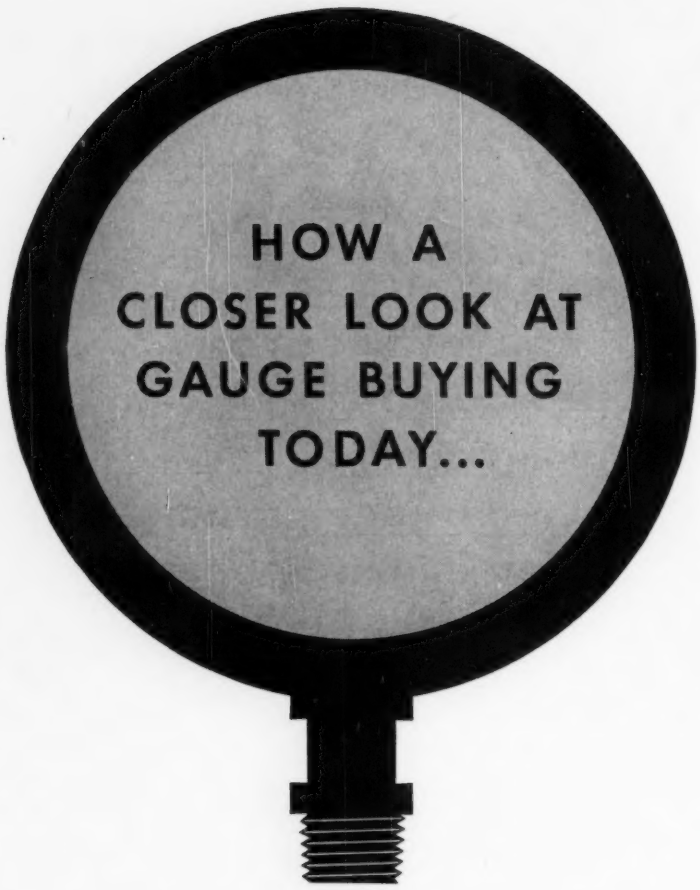
For more data on advertised products, use Readers' Service Cards, last page.

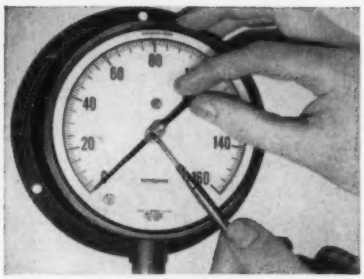


can help cut your gauge maintenance costs

Been taking gauges pretty much for granted? As to the price you pay, accuracy you buy, performance you get . . . gauges you use and their maintenance costs? Maybe it's time for a closer look at the United States Gauge line and how it can streamline buying. USG features the most comprehensive line of indicating dial pressure gauges you can draw on . . . in range of case styles, materials and sizes, in pressure ranges and in price . . . up to the finest gauges money can buy. The *completeness* of the USG line can help you avoid over-buying, under-buying, help you get exactly the gauge performance you pay for . . . from one source! As shown at right, exclusive USG design features even help cut maintenance costs. Check your USG distributor for your next gauge requirement. See the Yellow Pages, or write for catalogs and name of your nearest USG distributor, today.

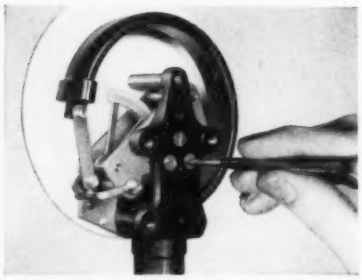
UNITED STATES GAUGE
Division of American Machine and Metals, Inc., Sellersville, Pa.

Find Your Nearest Distributor in the 'Yellow Pages'



NOTE that with a USG Supergauge®, complete recalibrations can be made faster than with any other process gauge. For example: "zero shift" adjustments are made from the front with gauge in operating position, and without removing pointer from the shaft.

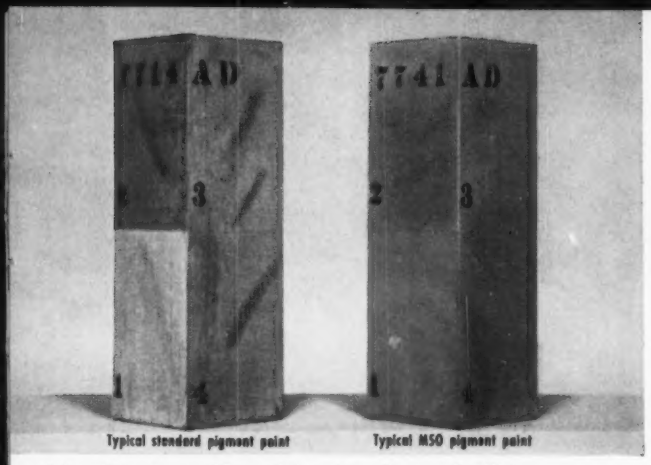
NOTE that with USG Mono-Unit design, internals are in one assembly which lifts out intact. Legend on dial gives full information for instant identification of model number and materials in components. More maintenance minutes saved!



NOTE that with USG Arc-Loc® movement, corrections for "scale shape" (linearity) errors and "range" adjustments are both made from the rear; no need to remove pointer and dial. USG's unique locking method eliminates creep during locking, saves more time! USG Supergauges meet A.S.A. standards for Grade AA Test Gauges, including accuracy to ½ of 1%. *Write for Catalog 1819.*

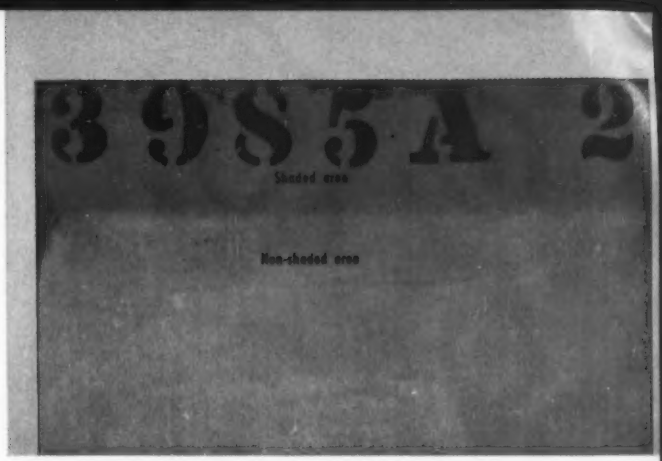
SAVINGS IN USG A-LINE, TOO!
Premium gauge construction at savings up to 40% of premium prices! Major economies in pressure measurement where you may now be buying more gauge than you need! Meets A.S.A. Grade A standards, including accuracy of 1%. Wide choice of options. Has Supergauge Mono-Unit design — cuts recalibration time. *Write for Catalog 305.*

For more data on advertised products, use Readers' Service Cards, last page.



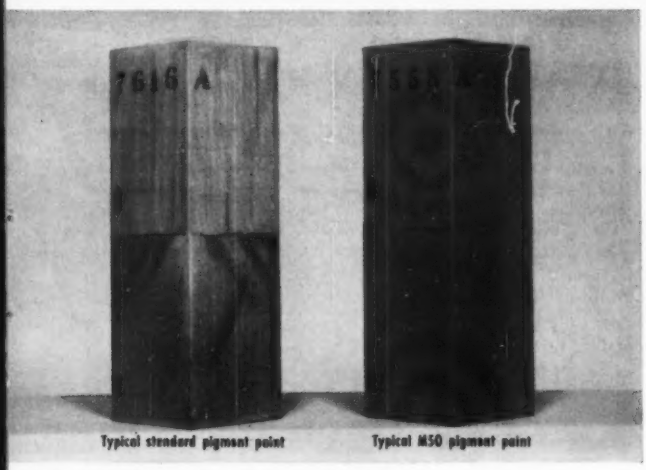
No objectionable whitening from chalking

Contrast these two exposure test panels . . . both show comparable metal finish paints. Same original colors. Same exposure (45° South, 2 yrs., 3 mos.). Notice bright color of *M50* paint, freedom from chalk.



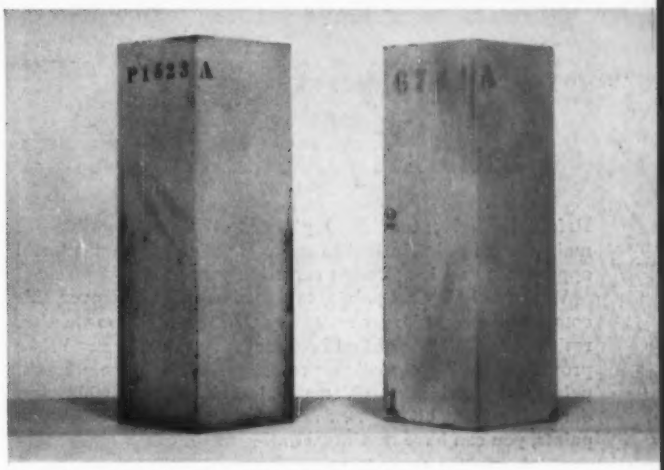
No appreciable fading from light action

Now look at this 9-year exposure test panel of an *M50* paint. Contrast area shaded by wooden panel holder with non-shaded area. Clearly, there has been practically no fading in this 9-year period.



No leaching from water action

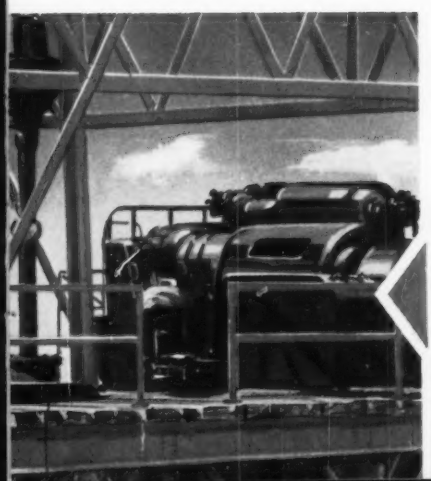
Examine the exposure panel at left. Notice the vertical brushmarks? Rain water leaching of the top coat permits brushmarks in undercoat to show through. In the panel at right, insoluble *M50* pigment prevents this film failure. Exposure 45° South, 2 yrs., 7 mos.



No discoloration in industrial atmosphere

Here are two exposure panels painted from the same can of *M50* paint. Both have been exposed 4 years, 45° South. The right one in normal atmosphere, the other in sulfur-laden industrial atmosphere. Notice no color difference has developed. No bilging.

Proof you get unique color stability in metal protective paints made with M50® pigment

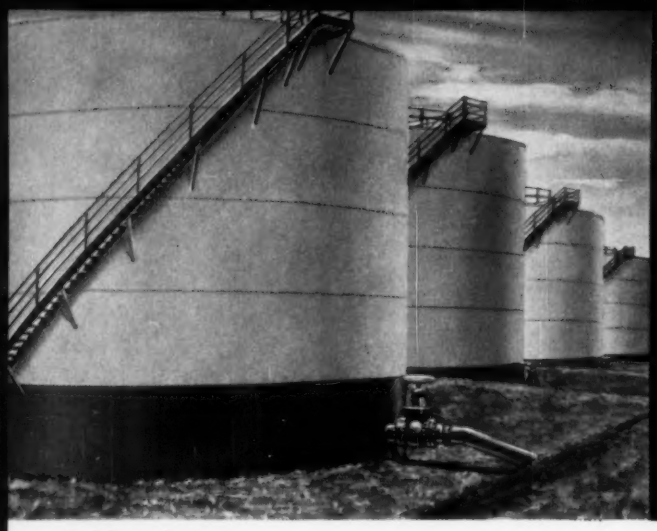


Drilling equipment looks better, needs less maintenance painting when painted with colorful *M50* anti-corrosion paints.

No need to amplify what the four illustrations above show. Plainly, *M50* basic lead silico chromate pigment permits your paint supplier to make paints with more color stability than ever before available in anti-corrosion paints . . . primers as well as finishes.

National Lead exposure tests demonstrate that these paints . . . both standard and heavy coat . . . also provide better and longer lasting anti-corrosion action, and never-before weather resistance. Some of the opportunities these new *M50* paints present are suggested on the following page. You'll think of others.

M50 pigment is a product of National Lead Company



Public relations.
Attractive tank farms that *stay* attractive longer.

Product identification.
Color-coded drums that *stay* colorful longer.

Two ways to make good use of the superior color stability of M50 pigment anti-corrosion paints

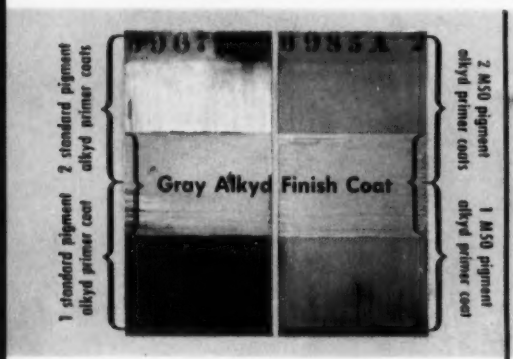
Before the advent of *M50* pigment, those responsible for maintenance painting had to make a choice between colorful appearance and long-lasting corrosion protection.

With *M50* pigment paints, exposure experience proves, this compromise is no longer necessary. *M50* paints have weather resistance . . . stay bright and colorful . . . and *at the same time* provide superior corrosion protection. With these unusual paints, color stability problems . . . leaching, fading, whitening, darkening from bilging . . . are eliminated. Now, with *M50* paints, you can have maximum anti-corrosion, maximum durability and, at the same time, long-lasting good appearance.

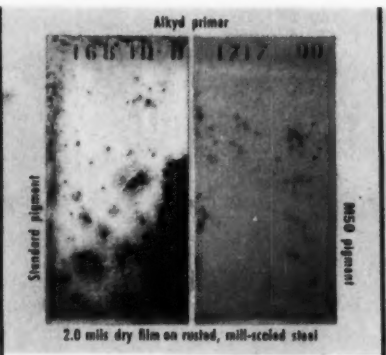
The illustrations above suggest two areas in which the combination of superior anti-corrosion action and superior color stability found in *M50* pigment paints can pay off handsomely. Note that in both, service is severe and colorful colors are needed. With *M50* paints, you repaint less often.

In your own operations there are bound to be many similar applications where specification of *M50* paints can lower your maintenance painting costs. Ask your regular paint supplier to make up suitable *M50* paints for your requirements.

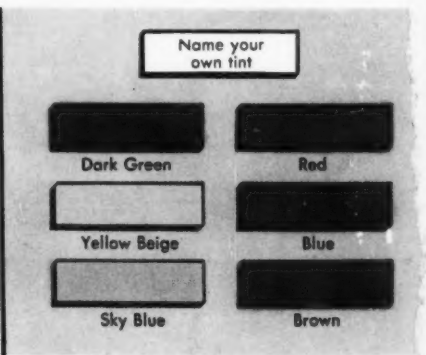
Why M50 Defense in Depth paints give anti-corrosion beyond all former concepts


1 standard pigment alkyd primer coat
2 standard pigment alkyd primer coats
Gray Alkyd Finish Coat
2 M50 pigment alkyd primer coats
1 M50 pigment alkyd primer coat

Exposed 9 years, 45°S. Each coat 1.5 mils
Proved corrosion and weather resistance



Exposed 45°S; 1 yr ind. atmos., 1 yr normal atmos.
Proved outstanding for film strength, durability



Colors above available in conventional and heavy-coat paints
A wide range of stable colors can be produced

Are you concerned with tank or structure maintenance painting in your firm? If so, you are invited: (1) to visit National Lead's Sayville, L.I. test station, where you will see the results of the 20 years research that lies behind the *M50* pigment particle and the more than 10 years of exposure testing that lies behind *M50* pigment Defense in Depth paints; (2) to send coupon below for National Lead booklet, "Defense in Depth" and typical *M50* tank paint specifications.

Next time you purchase, specify *M50* pigment paints. Any paint manufacturer can supply you.

M50 Defense in Depth

National Lead Company,
111 Broadway, New York 6, N. Y.

Gentlemen: Please send me the "Defense in Depth" booklet together with typical tank paint formulas and color chips that I can use in specifying M50-type tank paints.

Name_____ Title_____

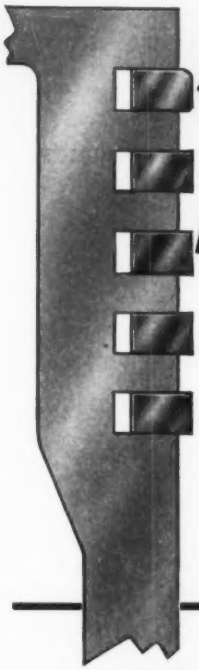
Firm or Dept._____

Address_____

City_____ State_____

ENGINEERING

NEWS YOU CAN USE ABOUT ENGINE AND COMPRESSOR PERFORMANCE

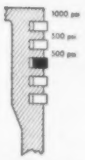


←HAVING TOP RING TROUBLE?

THE SOLUTION MAY BE IN THE THIRD GROOVE—NOT THE FIRST!

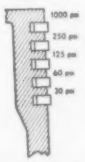
If you've had trouble with your top piston rings (excessive groove wear, groove damage, ring breakage, etc.) you won't need to be convinced that the top ring carries from 50 to 80% of the sealing load. Installing top rings of special, expensive materials is often not the answer. They may be shock-resistant but generally lack adequate wearing qualities. One likely solution is installation of a Cooktite sealing ring in the THIRD groove to relieve the load carried by the first ring. In an engine with a compression pressure of 500 psi and a firing pressure of 1000 psi, a Cooktite ring in the third groove will reduce the pressure differential on the top ring from a trouble-causing 750 psi to an easily-handled 500 psi. Ask a C. Lee Cook representative to explain in detail.

PRESSURE DIFFERENTIAL AT FULL FIRING PRESSURE



WITH COOKTITE SEALING RING IN THIRD GROOVE

500 psi



WITHOUT COOKTITE RING IN THIRD GROOVE

750 psi

MACHINED ROUND SHAPES FROM ANY MATERIAL

MADE TO YOUR BLUEPRINTS

Any machined round shape that can be produced by turning, milling, rolling, lapping or drilling can be made to your blueprints by C. Lee Cook Company. Any size from 1" to 60", with finishes down to 4 micro-inches and tolerances as close as .0002". And, there's almost no limit to the materials that can be machined. Send your blueprints for quotation or contact us for engineering recommendations. *Airtomic Products Division*, C. Lee Cook Company, Louisville 3, Ky.

WRITE FOR COOK'S NEW PISTON RING CATALOG

Sixteen-page catalog just off the press. Describes complete line of piston rings manufactured by C. Lee Cook Company, also the special rings of the Airtomics Division. For your free copy, write: C. Lee Cook Company, 950 South 8th Street, Louisville 3, Kentucky.

C. LEE COOK COMPANY

Division of Dover Corporation

Rings and Packings Since 1888

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...See THESE

SALES REPRESENTATIVES

WITH YOUR

FABRICATION SPECIFICATIONS

TUBING – FITTINGS

AND

SPECIALTIES

FELKERWELD

FOR ENDURANCE

on such metals as
Stainless Steel,
Stainless Clad Steel,
Inconel, Monel,
Nickel, Copper,
and Aluminum Bronze

OR COMMUNICATE WITH US DIRECT . . .

FELKER BROTHERS MANUFACTURING CO.

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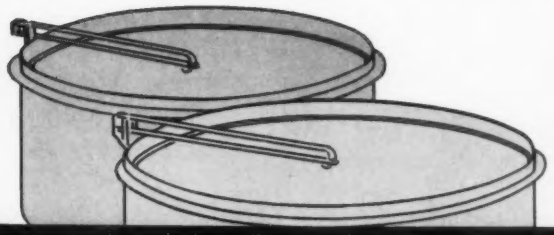

The HORTON *Fabric* SEAL

. . . sets new performance standards

Two special features combine to make the all-new Horton Fabric Seal the tightest fitting fabric seal ever offered . . . and provide standards of performance never before possible with a fabric type seal.

- **New sealing band material,** only recently developed, fulfill all of CB&I's rigid and long-sought requirements for product resistance, abrasion service and durability.
- **New design** insures a positive centering force for the roof and holds the sealing band in *intimate* contact with the tank shell for the full travel of the roof . . . even if the tank is out-of-round.

Prolonged laboratory tests and field service under the most severe conditions have proven the seal's superlative performance in *safety, durability* and *service.* For further details write the nearest CB&I office for our new brochure: *The Horton Fabric Seal.*

NOW . . . the closest fitting fabric seal available for Floating Roofs

SAFE

- Galvanized weather shield serves as electrical bond between roof and shell
- Explosive mixtures directly above liquid are eliminated

DURABLE

- Product and abrasion resistant buna N on tough nylon fabric for long wear, tight seal
- Interleafed galvanized weather shield protects sealing band from reflected sunlight, rain, snow, etc.

SERVICEABLE

- Full protection for oxygen sensitive stocks
- All moving parts immersed as protection against corrosion
- Intimate contact to tank shell, including irregularities, for full travel of floating roof

CB&I at your service . . .

CB&I's 35 years of building more floating roof tanks than all other manufacturers *combined* is at your service. For an accurate appraisal of the proper sealing mechanism for your storage conditions, contact your nearest CB&I office.

Chicago Bridge & Iron Company

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston • Kansas City (Mo.)
New Orleans • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • South Pasadena • Tulsa
Plants in Birmingham • Chicago • Salt Lake City • Greenville, Pa. • New Castle, Delaware
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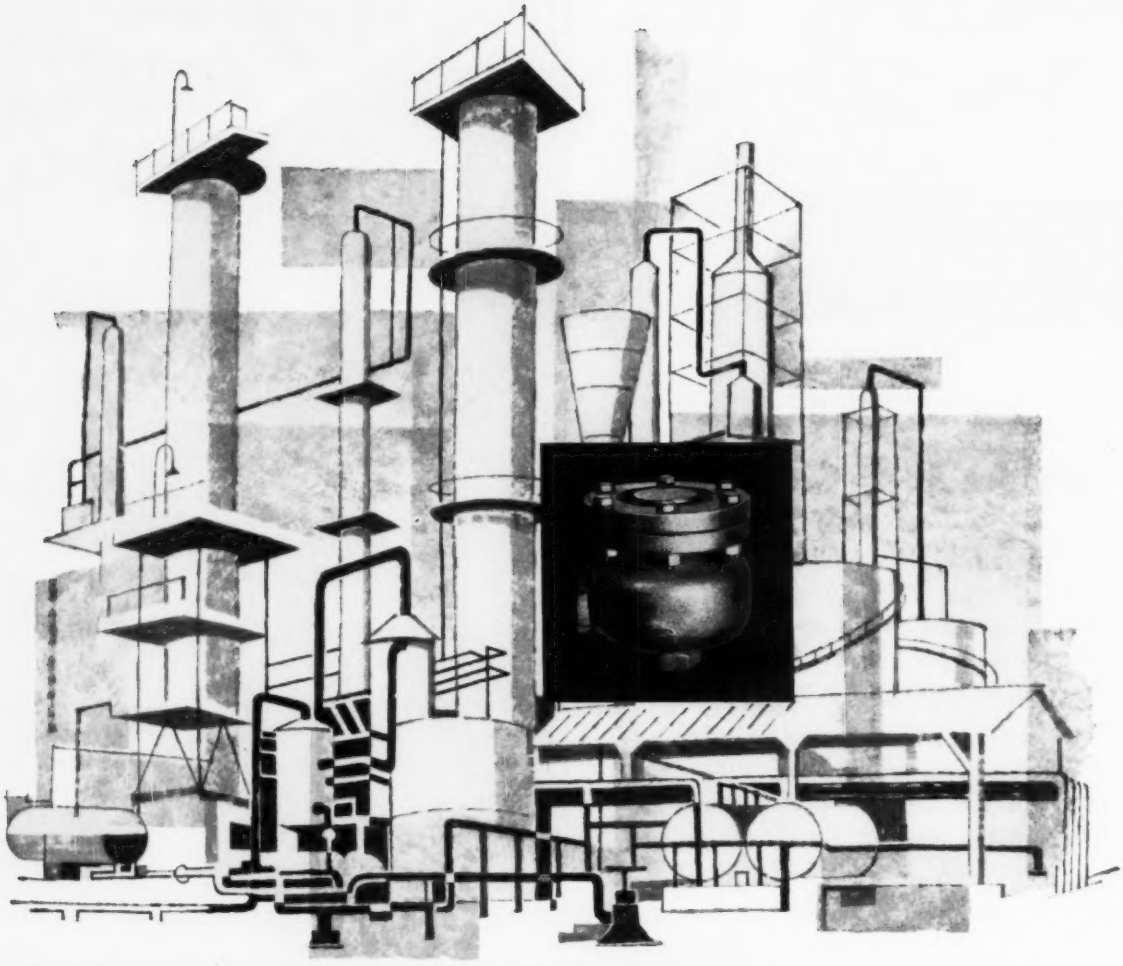
P80CB



THE ECONOMICS OF STEAM TRAP SELECTION

Initial cost versus installed cost

Everybody wants to save money in the purchase of steam traps, or anything else.

But a wise buyer will recognize that the *real cost* relates to the entire useful life of his plant, and that selection of the most efficient trap for a given application is an important consideration.

Compare the efficiency of Nicholson traps with that of so-called "bargains" and you'll see why plant engineers responsible for successful operation usually insist on Nicholson.

ST-102

NICHOLSON

OF WILKES-BARRE

W. H. Nicholson and Co. • 14 Oregon Street • Wilkes-Barre, Pa.

Distributors in all principal cities

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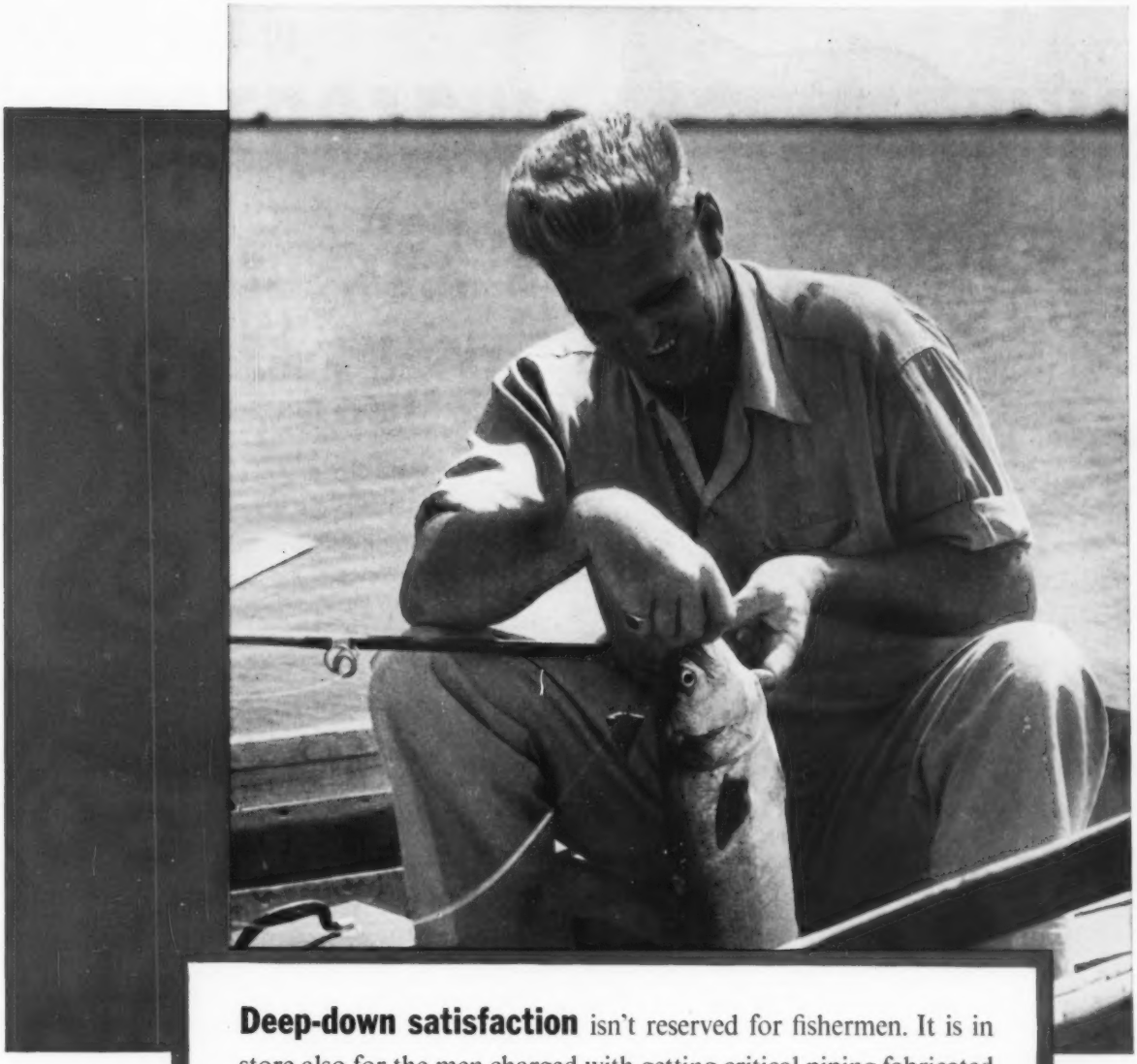

Deep-down satisfaction isn't reserved for fishermen. It is in store also for the men charged with getting critical piping fabricated and erected in their power or processing plants . . . provided they delegate such work directly to experienced specialists. Ask us in.

W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

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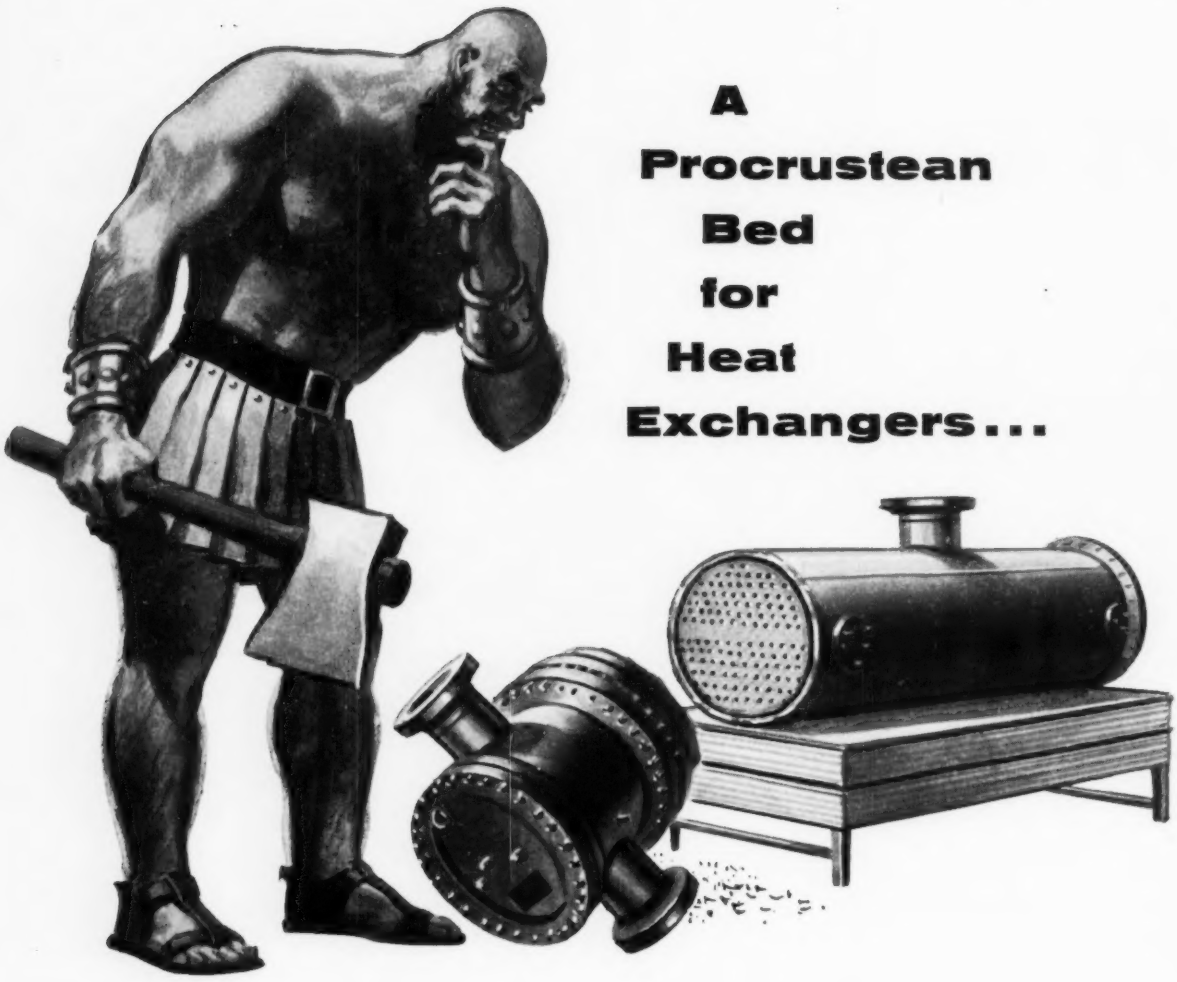

A Procrustean Bed for Heat Exchangers...

Mythological Procrustes stretched his victims to fit his bed when they were too short and cut off the surplus when they were too tall.

You can avoid this necessity by checking with Griscom-Russell the next time you are looking for heat exchange equipment.

Griscom-Russell has for over 90 years offered an extremely wide line of bare and finned tube heat transfer equipment for all industries — we can give you exactly what you need.

And you can be assured that G-R equipment is the best. G-R's reputation as one of the most engineering and research-minded companies in the field means you get designs that are the best available—or that special equipment will fit your needs exactly and at the lowest cost. Griscom-Russell's large plant, modern equipment and experienced working force mean that your equipment will be properly constructed.

You can stretch your dollars and shorten your problems by talking to your G-R representative. Let him tell you all about us now — or the next time you need heat exchange equipment.

Specialists in the engineering and construction of heat exchange equipment

air, gas and liquid heat exchangers, coolers and heaters —finned and bare tube, evaporators, steam generators, condensers, tank heaters, air-cooled fin-fan exchangers, sea water distilling plants, helically and longitudinally finned tubing, and many other products.

Griscom-Russell

A GENERAL PRECISION COMPANY

THE GRISCOM-RUSSELL COMPANY
MASSILLON, OHIO
A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

GR 397.

For more data on advertised products, use Readers' Service Cards, last page.

what's new in
PETROLEUM ENGINEERING
at Badger?

With more than a dozen current projects ranging from a simple pipe still to a 100,000 bpsd "grass-roots" refinery, Badger is the newsmaker in petroleum engineering.

You can learn more about many of these interesting projects when you visit the Badger Booth at the Fifth World Petroleum Congress Exposition. Just step up to the "do-it-yourself" control console where Badger projects are listed by name . . . select those in which you are interested . . . then press the appropriate pushbuttons. A color photo and informative printed story on each project will light up on the exhibit wall.

Badger will also feature products of its Manufacturing Division at the Exposition. Included will be displays of S-R Expansion Joints and Water Evaporators. Sales engineers from all Divisions will be on hand and will welcome an opportunity to show you how Badger services and products can serve you.

Fifth World Petroleum Congress Exposition, Coliseum, New York, June 1-5

***built by* BADGER**

INTERNATIONAL DESIGNERS • ENGINEERS • CONSTRUCTORS

THE BADGER COMPANIES

Badger Manufacturing Company Cambridge • New York • Houston • Canadian Badger Company Ltd. Toronto, Ontario, Canada • Badger N.V. The Hague, Holland • Badger Limited London, England • Badger (Belgium) S.A. Brussels, Belgium • Badger (France) S. à R.L. Paris, France

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with Davison Catalysts

Your stack carries away regeneration gases —not catalyst—when you put Davison in your unit. Here's why:

With Davison Catalysts you get the lowest amount of unretainable fines.

With Davison Catalysts you get lower attrition. The lower breakdown rate of Davison Catalysts means you get the fines you need without light particles escaping up the stack.

The reason: *balanced density.* There's a Davison Catalyst to suit your application. Write Department 3912, today for Product Service Bulletin No. 59-101.

W.R. GRACE & CO.
DAVISON CHEMICAL DIVISION
BALTIMORE 3, MARYLAND

Oakite ECP
engineered cleaning program

helps two-man crew strip tank bare in matter of hours

Rust-spotted, oil-splotched and peeling, an oil storage tank cried out for repainting. But stripping the old paint and soil had previously taken many tedious—and costly—man-hours of wire brush work. When refinery called in the Oakite engineer, he drew up an ECP, including a recommendation to strip tanks by the Oakite Hot Flow-On method. A heated solution of Oakite Stripper M-3 was flowed onto the tank surface through a perforated pipe "rake," recovered in a canvas trough, and recirculated. In just a few hours a painting team had moved in and the two-man stripping crew was ready to tackle another unsightly tank.

WHAT IS OAKITE ECP? It's an *Engineered Cleaning Program* that stresses chemical cleaning. It's engineered specifically for your refinery, for your cleaning problems, and for each cleaning operation—tower by tower, valve by valve.

The Oakite engineer lends personal and experienced supervision to each phase of the program. He supplies detailed instruction based on practical knowledge of refinery cleaning needs. Each Oakite ECP is backed by a *laboratory* concentrating on chemical cleaning research, by *materials* known to make short work of refinery soils, by proved *methods*. Send for booklets. Oakite Products, Inc., 50B Rector Street, New York 6, N. Y.

SPECIALIZED INDUSTRIAL CLEANING
OAKITE
MATERIALS · METHODS · SERVICE
SCIENCE

Export Division Cable Address Oakite

Technical Service Representatives in Principal Cities of U. S. and Canada

In our 50th year.

Oakite ECP
your economy key

For more data on advertised products, use Readers' Service Cards, last page.

Smith
Forged Steel
Needle Valves... are designed and precision built to the same basic specifications which have made all SMITH gates and globes the popular choice of the Refinery, Chemical, Petrochemical and Process Piping industries. They are built to "take it" — to give longer, trouble-free life in service at lowest maintenance cost — yet they cost no more than competitive valves.

Smith FORGED STEEL Valves

THE LONG AND SHORT OF IT...

Figure 50

Figure 100

The FIGURE 100

. . . a rugged, union bonnet general service valve

- Forged steel body and union nut
- Stem, heat treated to 375 BHN
- 30% stronger rolled stem threads
- High temperature packing
- Cadmium plated bonnet, gland and gland nut
- Heavy duty air furnace malleable handwheel

The FIGURE 50

. . . a compact, bonnet-less valve, especially designed for instrument service

- Forged steel body
- Stem, heat treated to 375 BHN
- 30% stronger rolled stem threads
- Teflon packing
- Cadmium plated gland nut
- Heavy duty air furnace malleable handwheel

Also available for high temperature service
FIGURE 100A and FIGURE 50A
—with 18-8 stem
FIGURE 100B and FIGURE 50B
—all 18-8 construction

Write today for our new brochure containing complete engineering, material and dimension specifications

NEW ENGLAND VALVE Corporation

BOX 1047 • WORCESTER, MASSACHUSETTS

New England Valve Corp. of Canada, Ltd.
Factory & offices: 1 Seneca Avenue Port Credit, Ontario

GAS PLANT IN A HURRY!

IT SHOT UP IN THE MIDDLE OF STEELMAN FIELD

LIKE A GUSHER—THE FASTEST

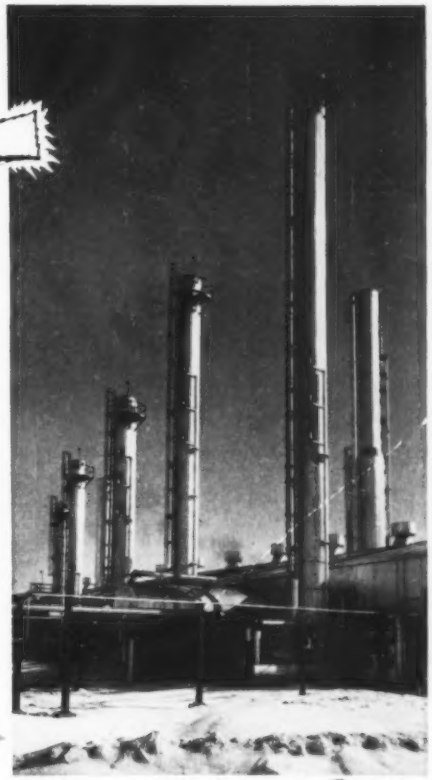
JOB OF ITS KIND EVER

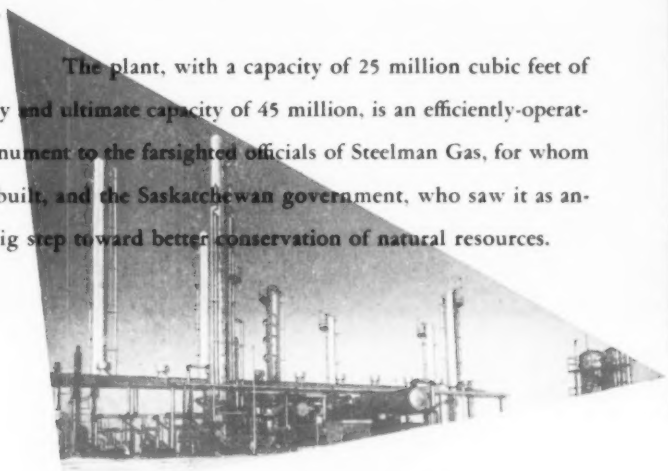
SEEN IN CANADA

—IN ONLY 4½ MONTHS!

In public speeches, Treco was commended by both the Saskatchewan minister of resources and the president of Steelman Gas Limited, not only for its speed, but for its quality workmanship as well.

The plant, with a capacity of 25 million cubic feet of gas daily and ultimate capacity of 45 million, is an efficiently-operating monument to the farsighted officials of Steelman Gas, for whom it was built, and the Saskatchewan government, who saw it as another big step toward better conservation of natural resources.





IF *you need a refinery or a gas, chemical or petrochemical plant in a hurry,*

....talk with the TRECO *man.....*

TRECO'S SPECIAL SERVICE DIVISION

Offers specialized, expert design and construction of waste-disposal systems and refinery and uranium-plant maintenance.

TRECO

A DIVISION of VITRO CORPORATION of AMERICA

The REFINERY ENGINEERING Company

FARMINGTON NEW YORK TULSA TORONTO

For more data on advertised products, use Readers' Service Cards, last page.

The extraction plant of Runnels Gas Products Corporation at Eunice, La., processes more than 300 mmcf. of pipeline gas daily to yield 5,000 barrels of liquid hydrocarbons (all the natural gasoline and butanes, 96% of the propane and 35% of the ethane.) Fuel-gas consumption is less than 3%. Absorption takes place at -40°F.

What's new in gas processing?

Anyone contemplating construction of a natural-gas processing plant, whether its purpose is treating, extraction or a combination of both, must first solve a puzzle with three complex variables. The efficiency and profitability of the plant depend on how well the puzzle is solved.

The first variable is, of course, the volume and composition of the inlet gas stream. The second is the market, if any, for extracted products, and the third is the legal and technical requirements for residue gas.

Major shifts in these variables make it profitable today to design gas-processing plants that differ radically from those built only a few years ago, and to locate them much farther away from the gas fields.

When you consider expansion...
the most important investment you can make
is in the creative ability of men.

FLUOR

Engineers and Constructors

For example, it is now advantageous to build large, highly efficient extraction plants to handle great volumes of lean Louisiana gas. Such plants serve the tremendously expanded LPG market for butanes and propane, and the petrochemical market for both of these, plus ethane. Because of the volume of gas, and the degree of extraction desired, a combination of extreme cold and light-oil absorption is the most efficient way to get the marketable hydrocarbons out. Refrigeration costs are more than offset by the use of smaller quantities of lighter oil, with consequent savings in pumping and stripping capacity.

As the natural-gas industry mushrooms, the trend is toward large plants, not only for hydrocarbon extraction but for sour-gas treating as well. And as the plants grow bigger, new levels of efficiency can be reached through methods that were impractical in smaller installations.

The development of new techniques for large-volume gas processing has been a Fluor contribution to the industry. The combined experience of the gas specialists in Fluor's Los Angeles and Midcontinent divisions represents a pool of advanced know-how that is unequaled anywhere.

The Fluor brochure, "Opportunities in Gas Processing," will be helpful to anyone planning construction of a processing facility. Write to Dept. 68, The Fluor Corporation, Ltd., 2500 South Atlantic Boulevard, Los Angeles 22, California.

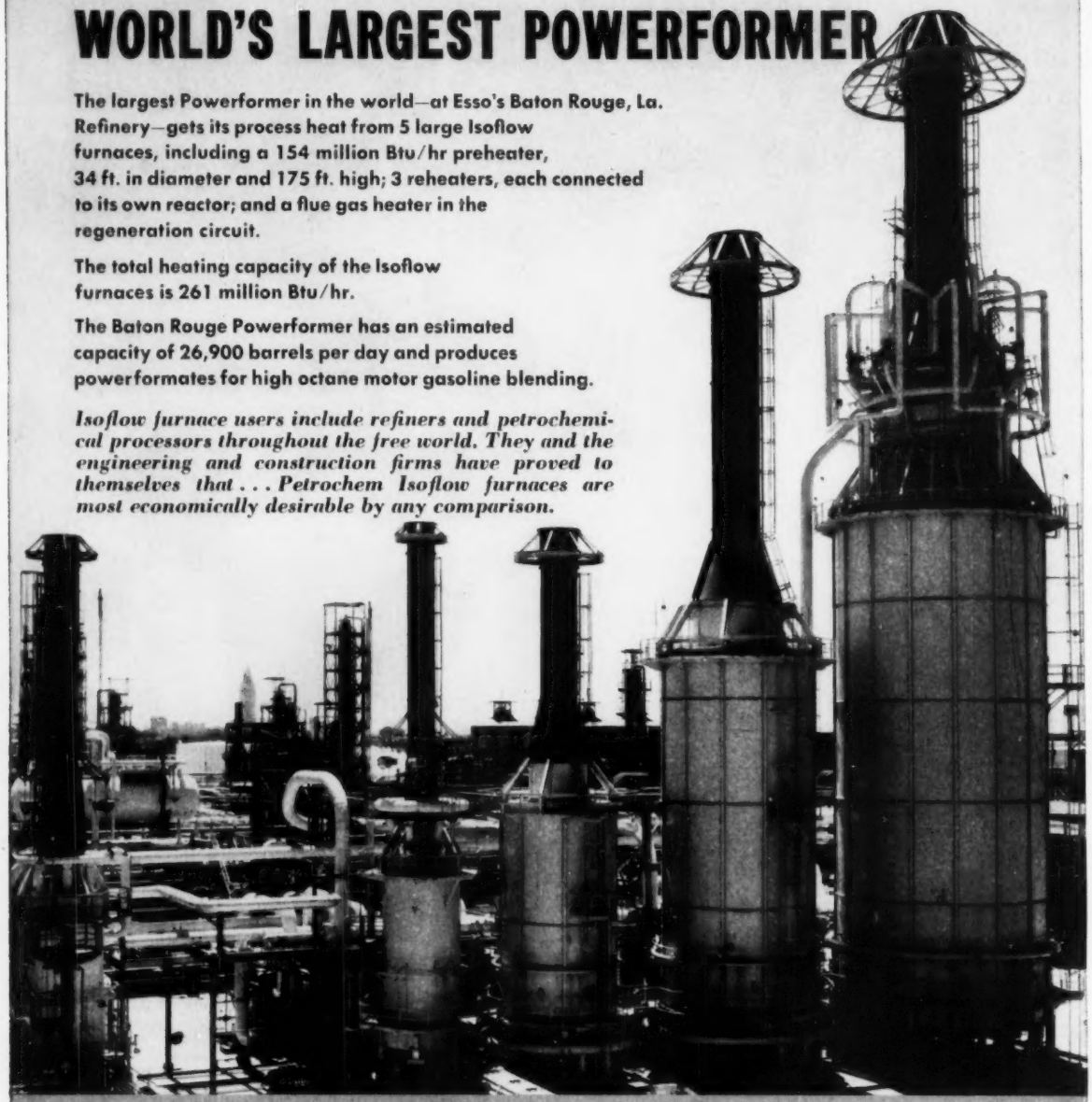
PETROCHEM-ISOFLOW HEATERS
charge
WORLD'S LARGEST POWERFORMER

The largest Powerformer in the world—at Esso's Baton Rouge, La. Refinery—gets its process heat from 5 large Isoflow furnaces, including a 154 million Btu/hr preheater, 34 ft. in diameter and 175 ft. high; 3 reheaters, each connected to its own reactor; and a flue gas heater in the regeneration circuit.

The total heating capacity of the Isoflow furnaces is 261 million Btu/hr.

The Baton Rouge Powerformer has an estimated capacity of 26,900 barrels per day and produces powerformates for high octane motor gasoline blending.

Isoflow furnace users include refiners and petrochemical processors throughout the free world. They and the engineering and construction firms have proved to themselves that . . . Petrochem Isoflow furnaces are most economically desirable by any comparison.

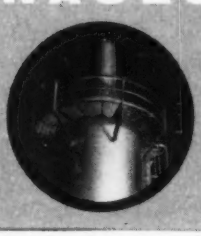


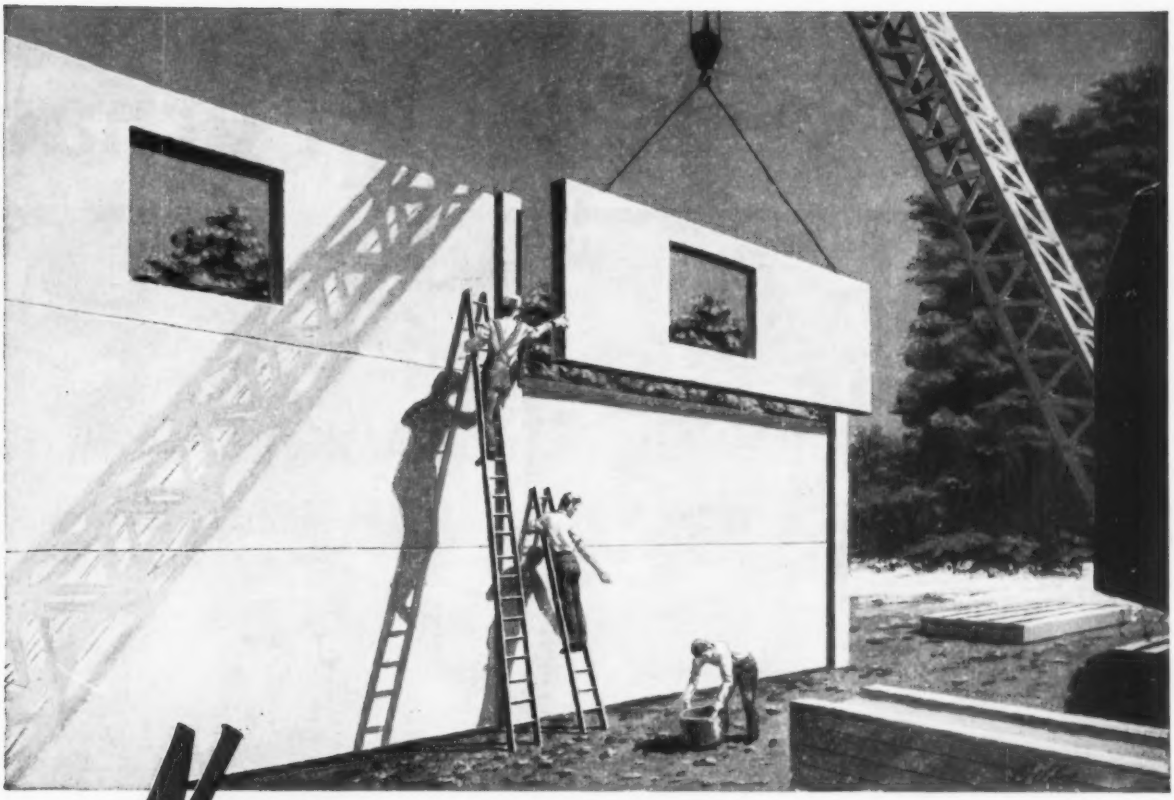
PETROCHEM-ISOFLOW FURNACES

UNLIMITED IN SIZE . . . CAPACITY . . . DUTY

PETRO-CHEM DEVELOPMENT CO., INC. • 122 EAST 42nd St., New York 17, N. Y.

REPRESENTATIVES: Rawson Co., Baton Rouge • Rawson-Houlihan Co., Houston • Wm. H. Mason, Tulsa • Lester Oberholtz, Los Angeles • Faville-Levally, Chicago • D. D. Foster, Pittsburgh • Turbex, Philadelphia • Flagg, Brackett & Durgin, Boston G. W. Wallace, Denver, Salt Lake City & El Paso International Licensees and Representatives: Birwelco Ltd., Birmingham, England • Societe Anonyme Heurtey, Paris, France • Societe Anonyme Belge Heurtey, Liege, Belgique • Heurtey Italiana S.P.A., Milan, Italy • Petrochem G.M.B.H., Dortmund, Germany • SETEA-S.A. Comercial, Industrial, y de Estudios Tecnicos, Buenos Aires, Argentine





Now Permanent Concrete Buildings

Erected in Hours!

DESIGN—Rackle provides professional assistance in building design and all phases of engineering.

MANUFACTURE—4000 to 5000 PSI lightweight Haydite concrete is conventionally reinforced and/or prestressed by Swiss-patented BBR system. Strict production and laboratory control insures positive strength in Rackle members.

DELIVERY—Rackle trucks deliver structural components to jobsite as soon as the foundation is poured.

ERECTION—Units are put into place as quickly as they are delivered. Columns are set first. Then beams. Finally channel roof deck. Small buildings can be set in 8 hours; a 30,000 sq. ft. warehouse in 40 to 60 hours.

FINISHING—Six inch thick pre-cast wall panels with plain or textured surfaces can be installed rapidly, or you can use any other architectural treatment you prefer.

From design to finished product, Rackle provides a complete concrete building engineered to individual specifications with speed and economy.

Rackle's new engineering and production technique makes *extra speedy* construction possible with permanent, maintenance-free concrete.

Engineered and cast to individual specifications at our Houston plant, Rackle structural members are trucked to your building site and erected in a matter of hours.

Initial cost is surprisingly low because of speed of construction, and when you build with concrete you continue to save for many years because concrete requires little or no maintenance and insurance rates are lower, too.

Write or call today for literature on building with Rackle.

THE RACKLE COMPANY OF TEXAS

PO BOX 15008 • HOUSTON • OR 2-1736

Serving the Texas Gulf Coast Only

Manufacturers of quality concrete products since 1870 . . . a wholly owned subsidiary of the Geo-Rackle and Sons Co., Cleveland, Ohio.

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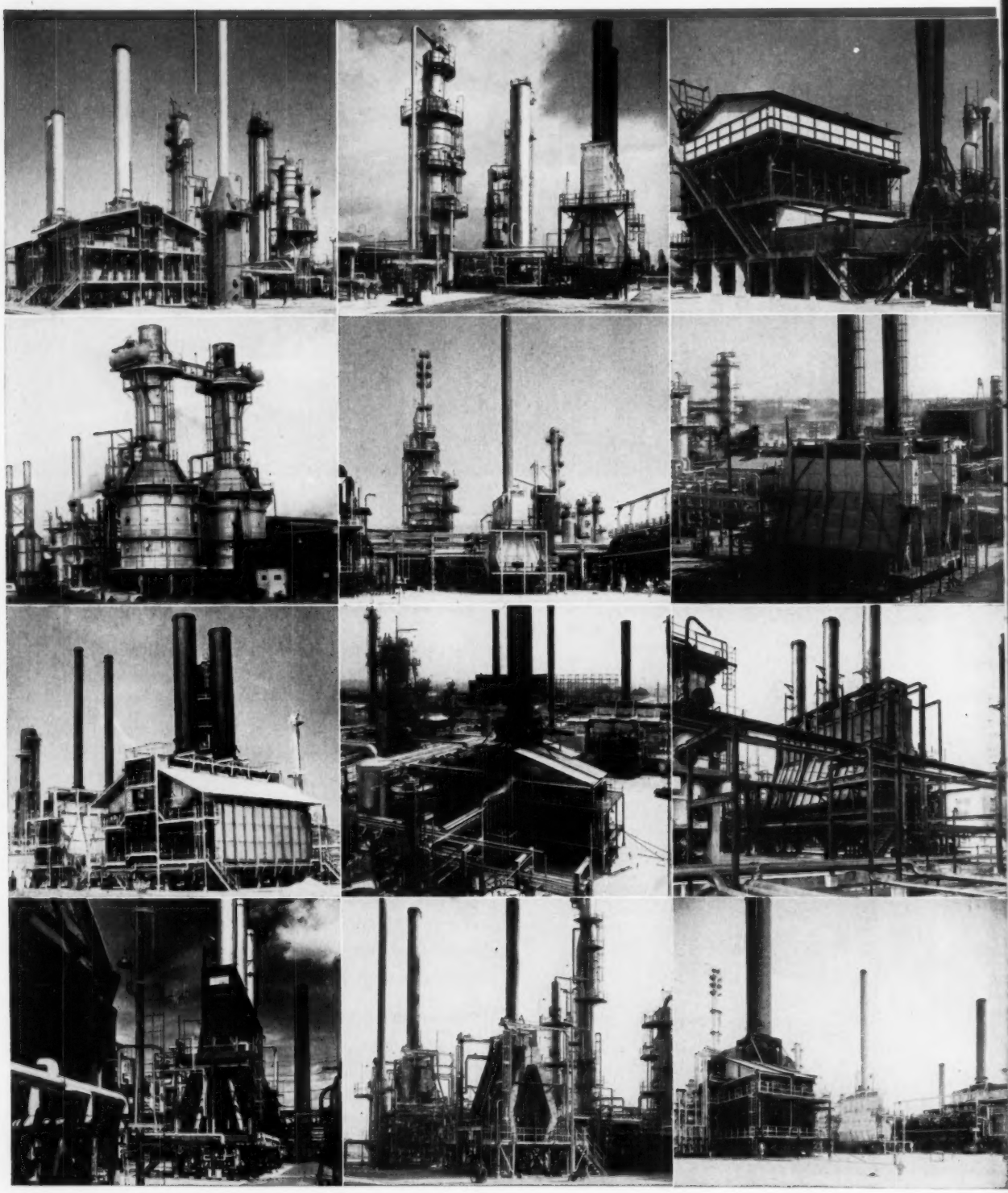
NOW–a Kellogg Furnace



For more data on advertised products, use Readers' Service Cards, last page.

for Each Processing Need

INDIVIDUALIZED DESIGNS ASSURE OPTIMUM INVESTMENT AND OPERATING ECONOMY

Furnaces are a major part of the total investment in a petroleum refinery or chemical plant—and vital to its production and income. Variances in operating efficiency or frequent time out for repairs can quickly offset the slight initial savings made with inadequately engineered or "standardized" equipment.

Designing and building furnaces to meet precisely *all* the many specific needs of each individual unit, and thus assure optimum return on investment, has been for over 30 years an integral part of The M. W. Kellogg Company's complete engineering and construction service.

With the recent expansion of this highly specialized furnace division, Kellogg now can offer its unique background in thermodynamics and furnace technology broadly to the process industries as an independent service—backed by the experience and facilities of the entire Kellogg engineering organization.

For details on Kellogg's economic approach to furnace investments, write Kellogg's Furnace Sales Division.

THE M. W. KELLOGG COMPANY
711 Third Avenue, New York 17, N. Y.
A SUBSIDIARY OF PULLMAN INCORPORATED

Companhia Kellogg Brasileira, Rio de Janeiro
Kellogg Pan American Corporation, Buenos Aires
Compania Kellogg de Venezuela, Caracas
The Canadian Kellogg Company, Limited, Toronto
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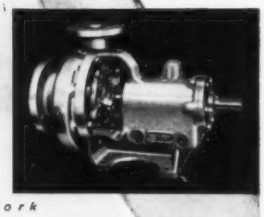
"PEERLESS PUMPS IT BEST!"

Pump Buyers are saying this about Peerless Process Pumps—



PEERLESS PUMPS

fmc FOOD MACHINERY AND CHEMICAL CORPORATION

Putting Ideas to Work

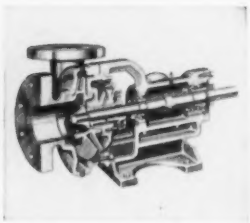
FOOD MACHINERY AND CHEMICAL CORPORATION

Peerless Pump Division

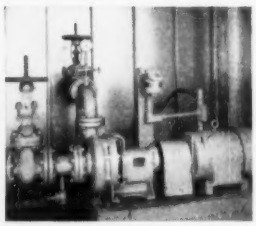
Plants: LOS ANGELES 31, CALIFORNIA and INDIANAPOLIS 8, INDIANA

Offices: New York, Atlanta, St. Louis, Phoenix, San Francisco, Chicago, Fresno, Los Angeles, Plainview and Lubbock, Texas, Albuquerque. **Distributors in Principal Cities.** Consult your telephone directory.

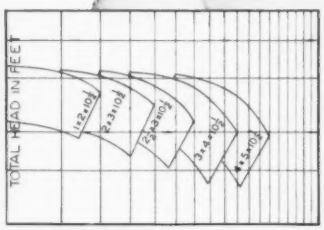
HERE ARE 4 CONVINCING REASONS WHY:



THEY OFFER the type of quality construction that measures up to any standard. Continual checking at every stage of manufacture guarantees the buyer performance he can count on in the field. *The best!*



THEY PROVIDE the performance you expect and pay for, backed by actual operating records of Peerless pumps in installations like yours. Durability, dependability, efficiency—*all proved in service.*



THEY MEET *exactly* every pumping requirement, handle any job in your system that calls for a pump. The *complete* Peerless range offers *all* types of chemical process pumps, in *all* sizes and frames.

AN EXAMPLE of Peerless research is this recently released bulletin on the effects of radial loads in process pumps, "MECHANICAL CONSIDERATION IN PUMP DESIGN." Request Bulletin No. EM-79.

"Ferulok"® flareless fittings in steel and stainless steel for fast, easy installations on either thin-wall or heavy-wall tubing from 1/16" to 2" O.D.

Only from Parker

so complete a range of tube fittings for process and instrument lines

Select the proper tube fittings for any of your process or instrumentation lines from hundreds of different sizes, shapes and alloys in the Parker fittings line.

Parker "Intru-lok" fittings for fast, easy assembly of low- and medium-pressure lines in metal or plastic tubing. Fittings come ready to use without disassembly.

"Triple-lok" flare-type fittings make up leak proof on high pressure, high temperature lines. They are ASME-approved, ideal where safety is vital.

Leak-free, vibration-proof "Ferulok"® flareless, bite-type fittings hold pressure-tight on thin-wall or heavy-wall steel or stainless tubing. For semi-permanent joints on critical applications, use "Braze-lok" fittings on O.D. tubing. And use "Weld-lok" for highest temperatures and pressures.

Call your Parker fittings distributor for prompt delivery of Parker fittings from local stocks. He can also offer expert advice on any process or instrument tubing installation.

"Intru-lok" brass or aluminum flareless fittings for fast, easy installations on either plastic or metal tubing. (1/8" to 1" O.D.)

"Weld-lok" in steel and stainless steel for highest temperatures. "Braze-lok" in stainless steel, monel and Naval brass, silver-brazed for strength and reliability. (1/8" to 2" O.D.)

"Triple-lok" 37° flare-type fittings in brass, aluminum, stainless, and cadmium-plated steel for safe, trouble-free service. (1/8" to 2" O.D.)

Parker FITTINGS AND HOSE DIVISION

17325 Euclid Avenue • Cleveland 12, Ohio

A DIVISION OF PARKER-HANNIFIN CORPORATION

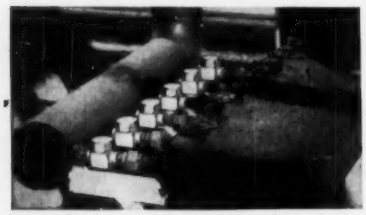
For more data on advertised products, use Readers' Service Cards, last page.

Because there's no time for Trap Trouble in the Oil Business . . .

by John W. Ritter, Test Engineer
SARCO Company, Inc.

No industry looks with any favor on the prospect of even a partial shutdown. In petroleum refining, the emphasis on continuous, efficient operation is especially strong, because unscheduled shutdowns can be fabulously expensive and often lead to product waste or reprocessing.

Refinery engineers sometimes look upon



Steam Trap manifold for steam tracing, installed in the Cat Reformer at Phillips Kansas City plant.

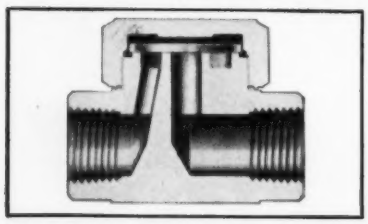
the steam trap as a necessary nuisance, because if the trap does fail, replacement or repairs can cause wasteful downtime.

Refineries use steam traps to do a wide variety of jobs. Applications include drips on transmission lines, tracer lines, tank coils, reboilers, and dozens of other process applications—not to speak of space heating.

Steam traps operating in refineries must function satisfactorily on low pressure or exhaust steam and up through high-pressure, high-temperature ranges, even though outside temperature may vary from subzero to subtropical.

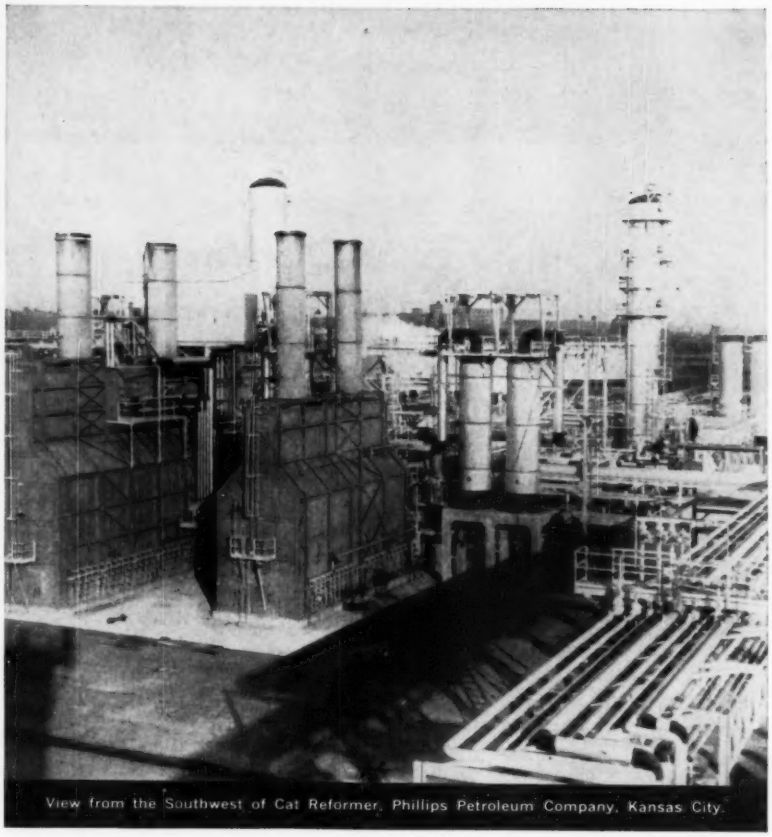
Sarco Thermo-Dynamic Steam Traps have found favor in many types of refinery operations, and the answer lies in the simplicity with which TD's handle condensate and prevent steam loss.

With only one moving part – the stain-



This 3-part Sarco TD Steam Trap has only one moving part – the hardened, polished steel disc.

less steel disc – the TD can be inspected and serviced in 40 seconds. No adjustment is ever needed, and TD Steam Traps are accumulating enviable records of long, trouble-free service in the refinery industry.



View from the Southwest of Cat Reformer, Phillips Petroleum Company, Kansas City.

Phillips installs 200 SARCO TD traps on new catalytic reformer

In March, 1954, Phillips Petroleum Company installed its first Sarco TD Steam Trap on a main line drip, on 150 psig steam pressure. Later TD-50's were installed on many different applications. When Phillips built its new Catalytic Reformer Unit (No. 17) some 200 TD Steam Traps were installed. (There are now 1800 TD-50's throughout the refinery.) When the traps are TD's, they need not be a "Necessary Nuisance." Rather, they can be as reliable, efficient and versatile as any other piece of equipment in this field.

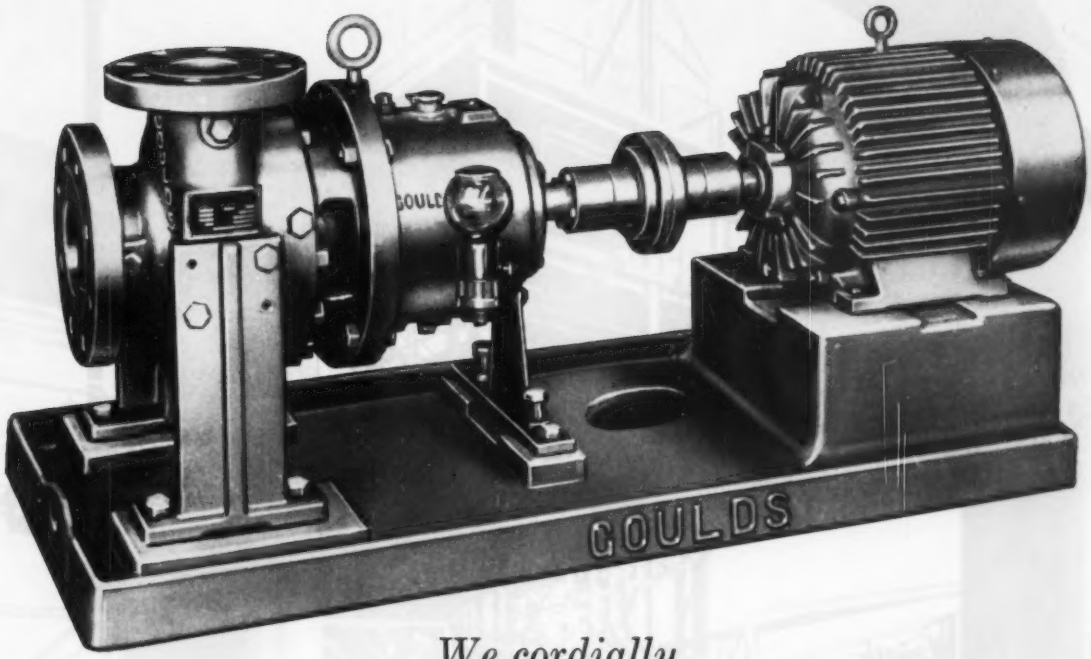
Write today for literature on the TD Steam Trap and other Sarco traps. Sarco can give you impartial advice on *Production Planned steam trapping because . . .* 7946

SARCO
COMPANY, INC.
635 Madison Ave., New York 22, N. Y.

Only Sarco makes all 5 types:
Thermo-Dynamic • Thermostatic • Liquid Expansion*
Float Thermostatic • Bucket

*U. S. Pat. No. 2,817,353 T.M. Reg. U. S. Pat. Off.

STEAM TRAPS • TEMPERATURE CONTROLLERS • STRAINERS • HEATING SPECIALTIES



We cordially
invite your inspection of our
process pump. On display at
Booth No. 252-53, the
International Petroleum Exposition,
Tulsa, Oklahoma—May 14-23

GOULDS PUMPS

FOR PRINTED DATA, write Goulds Pumps, Inc.,
Dept. PR-59, Seneca Falls, N.Y., for Bulletin 724.1

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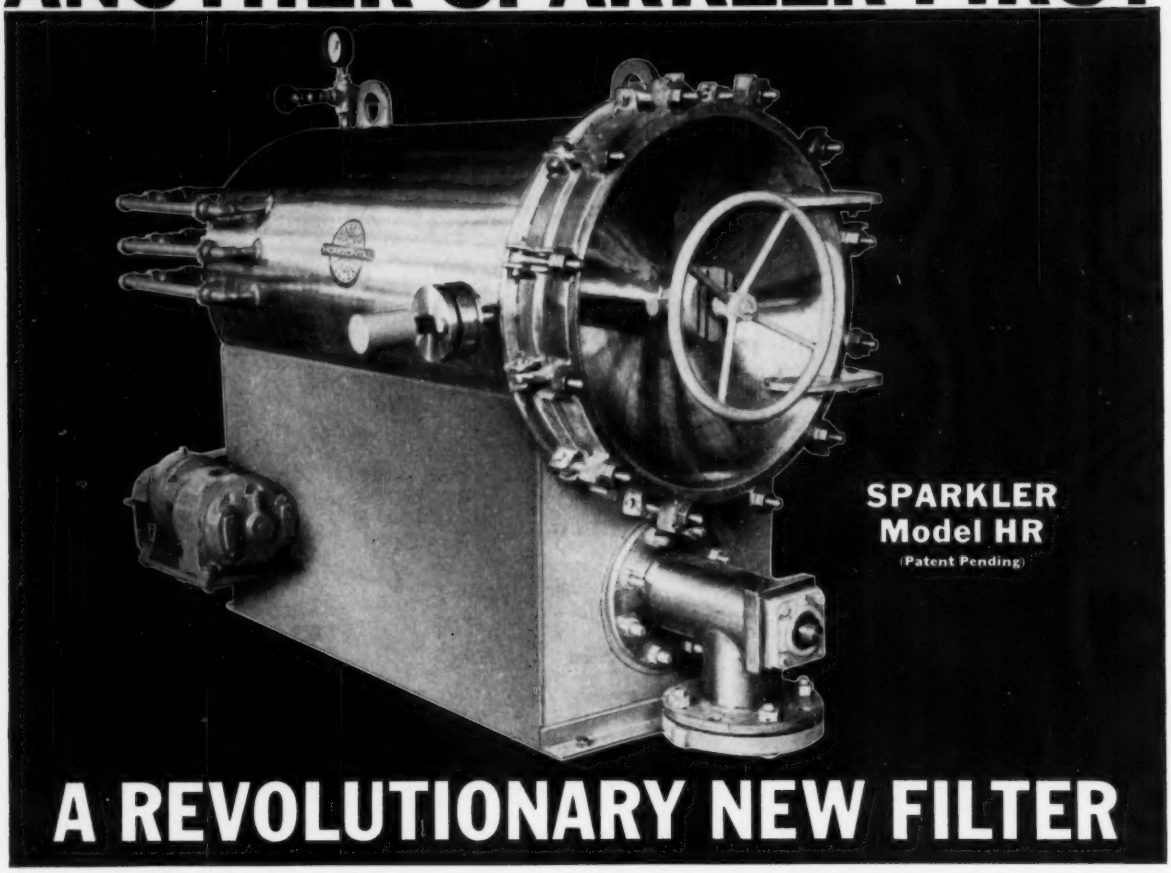
ANOTHER SPARKLER FIRST



A REVOLUTIONARY NEW FILTER

NOW–HORIZONTAL PLATE CAKE STABILITY PLUS DRY CAKE DISCHARGE. –ALL AUTOMATIC–

This filter has all the operating features filtration engineers have dreamed of for years—Write for details.

SPARKLER FILTERS

SPARKLER MANUFACTURING CO.
MUNDELEIN, ILLINOIS U. S. A.

Sparkler International Ltd., Manufacturing Plants at Leliegracht 9, Amsterdam, Holland; Toronto, Ontario, Canada; Italy and Australia.

FILTRATION ENGINEERING AND MANUFACTURING EXCLUSIVELY FOR OVER 30 YEARS

LINDE packaged oxygen plant sets nine-year record for availability!

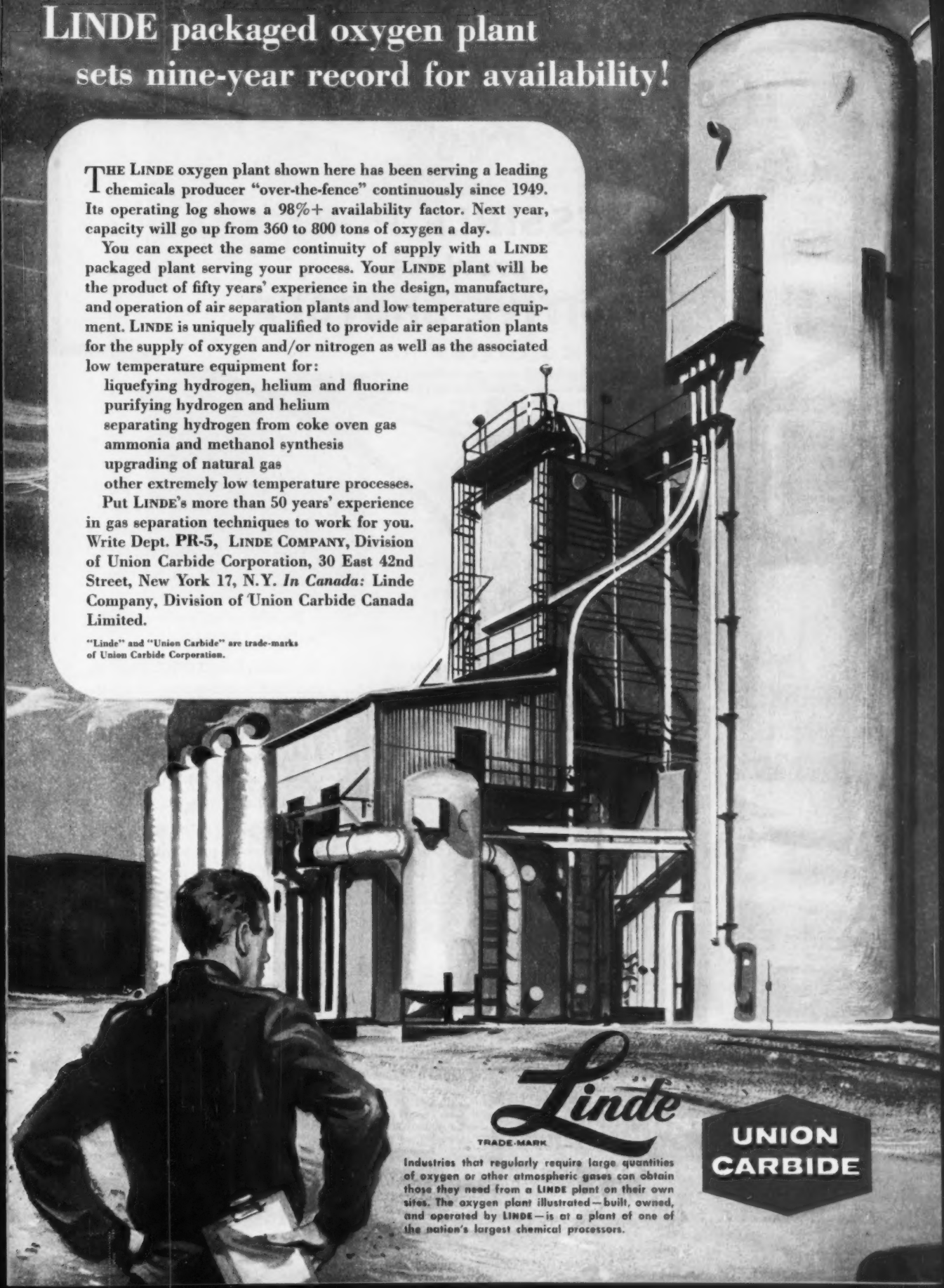
THE LINDE oxygen plant shown here has been serving a leading chemicals producer "over-the-fence" continuously since 1949. Its operating log shows a 98%+ availability factor. Next year, capacity will go up from 360 to 800 tons of oxygen a day.

You can expect the same continuity of supply with a LINDE packaged plant serving your process. Your LINDE plant will be the product of fifty years' experience in the design, manufacture, and operation of air separation plants and low temperature equipment. LINDE is uniquely qualified to provide air separation plants for the supply of oxygen and/or nitrogen as well as the associated low temperature equipment for:

liquefying hydrogen, helium and fluorine
purifying hydrogen and helium
separating hydrogen from coke oven gas
ammonia and methanol synthesis
upgrading of natural gas
other extremely low temperature processes.

Put LINDE's more than 50 years' experience in gas separation techniques to work for you. Write Dept. **PR-5**, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N.Y. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

"Linde" and "Union Carbide" are trade-marks of Union Carbide Corporation.



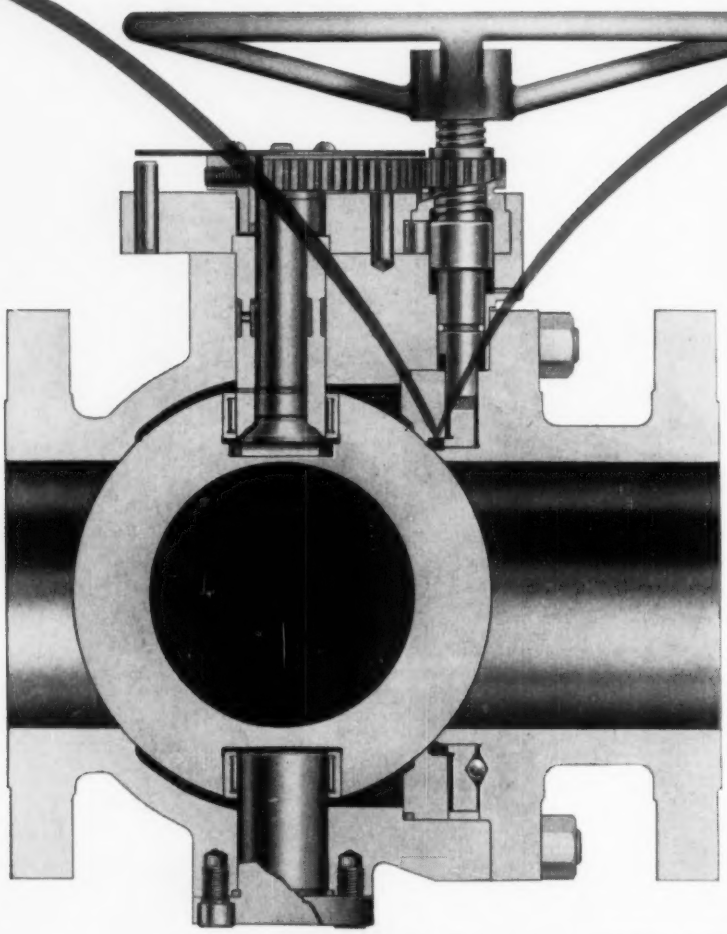
Linde
TRADE-MARK

UNION CARBIDE

Industries that regularly require large quantities of oxygen or other atmospheric gases can obtain those they need from a LINDE plant on their own sites. The oxygen plant illustrated—built, owned, and operated by LINDE—is at a plant of one of the nation's largest chemical processors.

HYDRIL BALL Type "K" PLUG VALVES

COMPRESSIBLE PORT SEAL
provides
POSITIVE SHUTOFF



Hydril Ball Plug Valves achieve a positive seal against pressure from either direction because the fully enclosed packing ring is *mechanically pressed* tightly against the spherical plug and its seat after the valve is closed.

No other valve has this *controlled* port sealing feature.

SEEP-PROOF, BUBBLE PROOF. The fully confined packing ring is tightly squeezed against plug and seat so that it flows into surface imperfections, around sediment . . . even closes scratches that may occur on the sealing surfaces.

PORT SEAL RETRACTS for easy operation. The mechanical pressure against the port seal is released before plug rotation commences to eliminate seal ring wear and assure easy operation.

•

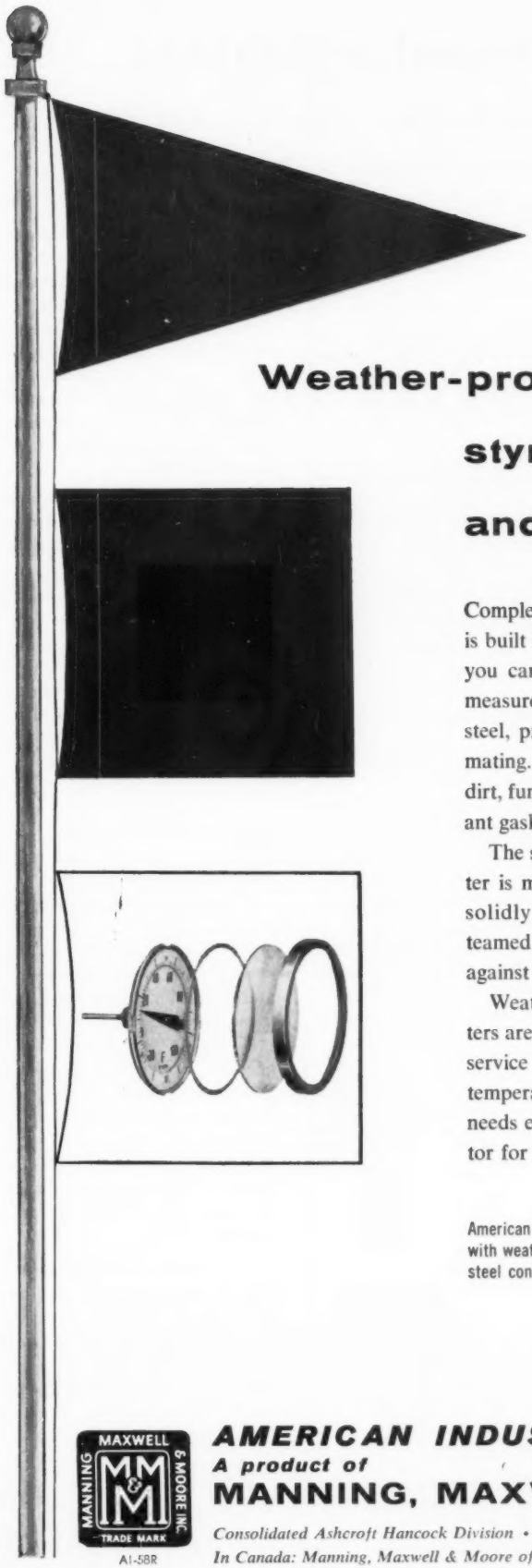
Write for catalog describing Hydril Ball Plug Valves in full detail.

Another dependable Hydril pressure-control product

HYDRIL COMPANY

714 W. Olympic Boulevard, Los Angeles 15, California

Sales offices: Bakersfield, Los Angeles, Ventura, California; Harvey, New Iberia, Louisiana; Oklahoma City, Tulsa, Oklahoma; Rochester, Pennsylvania; Corpus Christi, Dallas, Houston, Midland, Odessa, Texas; Casper, Wyoming; Farmington, New Mexico; New York, New York; Calgary, Edmonton, Canada.



Weather-proof construction stymies erosion and corrosion

Complete protection against erosion and corrosion is built into American Bi-Metal Thermometers, so you can always be sure of accurate temperature measurement. Both case and bezel are stainless steel, precisely fitted and gasketed to insure snug mating. Whatever the weather, rain, sand, dust, dirt, fumes and frost are sealed out by a heat-resistant gasket between case and thick cover glass.

The stem of the American Bi-Metal Thermometer is mirror-smooth stainless steel. All joints are solidly welded. Top resistance to corrosion is teamed with strength, rigidity and tight closure against process pressures.

Weather-proof American Bi-Metal Thermometers are noted for high sustained accuracy and long service life. There are mounting styles, dial sizes, temperature ranges and stem lengths to meet your needs exactly. Ask your industrial supply distributor for help in proper selection.

American Bi-Metal Thermometer with weather-proof stainless steel construction.

MAXWELL MANNING M&M & MOORE INC. TRADE MARK

A1-58R

AMERICAN INDUSTRIAL THERMOMETERS

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Stratford, Connecticut

In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.

Trapping Standardization

. . . steam trap standardization plus standardized hook-ups spell lower maintenance costs

An important weapon in the fight against rising maintenance costs is standardization. It can reduce the variety of maintenance problems and simplify those which remain.

Since we specialize in steam traps we'd like to offer some suggestions for a trapping standardization program. Such a program involves standardization on one make of trap and standardization of hook-ups.

Trap Standardization

The advantages of standardizing on a single make of trap are important and can make a big difference in the cost and ease of repairs because—

1. You can carry a more complete stock of repair parts with a smaller inventory.

2. Maintenance personnel has the opportunity to become expert on one make rather than be "jacks of all traps."

3. As an exclusive user of one make of traps you become a preferred customer of your trap representative and can be sure of getting the best possible service.

4. You can enjoy the advantages of standardized hook-ups.

Standardized Hook-ups

Standardized hook-ups facilitate and reduce the cost of both original installation and maintenance. By adopting standards for the dimensions of all fittings, including nipples, each hook-up for a given size of trap is identical and can be fabricated in the pipe shop.

Unions should be used so that when a trap needs repair, the unions can be uncoupled, the trap lifted from the line and a spare carrying identical length nipples and half unions slipped into place. In as little as a minute or two a faulty trap can be replaced. The faulty trap can go back to the storeroom for repair when convenient and then be put into stock as a spare.

Figure 1 shows a typical standardized hook-up used by a major chemical manufacturer. Note how

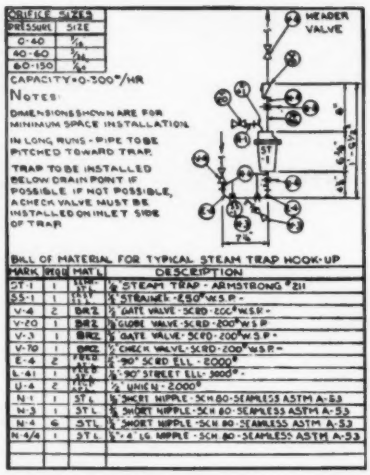

ORIFICE SIZES
PRESSURE | SIZE
0-40 | 7/32
40-60 | 3/16
60-150 | 1/4
CAPACITY=0-300#/HR
NOTES:
DIMENSIONS SHOWN ARE FOR MINIMUM SPACE INSTALLATION.
IN LONG RUNS - PIPE TO BE PITCHED TOWARD TRAP.
TRAP TO BE INSTALLED BELOW DRAIN POINT IF POSSIBLE. IF NOT POSSIBLE, A CHECK VALVE MUST BE INSTALLED ON INLET SIDE OF TRAP
HEADER VALVE
BILL OF MATERIAL FOR TYPICAL STEAM TRAP HOOK-UP
MARK | DTY | MAT'L | DESCRIPTION
ST-1 | 1 | STEEL | ½" STEAM TRAP - ARMSTRONG #211
SS-1 | 1 | STEEL | ½" STRAINER - 250# W.S.P. -
V-4 | 2 | BRZ | ½" GATE VALVE - SCRD - 200# W.S.P. -
V-20 | 1 | BRZ | ½" GLOBE VALVE - SCRD - 200# W.S.P.
V-3 | 1 | BRZ | ½" GATE VALVE - SCRD - 200# W.S.P.
V-70 | 1 | BRZ | ½" CHECK VALVE - SCRD - 200# W.S.P. -
E-4 | 2 | MAL | ½" - 90° SCRD ELL - 2000#
E-41 | 1 | MAL | ½" - 90° STREET ELL - 3000#
U-4 | 2 | MAL | ½" UNION - 2000#
N-1 | 1 | ST L | ½" SHORT NIPPLE - SCH 80 - SEAMLESS ASTM A-53
N-3 | 1 | ST L | ½" SHORT NIPPLE - SCH 80 - SEAMLESS ASTM A-53
N-4 | 6 | ST L | ½" SHORT NIPPLE - SCH 80 - SEAMLESS ASTM A-53
N-4/4 | 1 | ST L | ½" - 4" LG NIPPLE - SCH 80 - SEAMLESS ASTM A-53

Fig. 1—Typical standardized installation hook-up used by a leading chemical manufacturer.

the hook-up provides the following advantages:

1. Test valve in trap cap permits fast, easy checking of trap operation.
2. Strainer ahead of trap protects it against dirt and scale.
3. Blowdown valve in strainer provides easy cleaning.
4. Check valve in discharge line isolates trap when test valve is opened.
5. Shut-off valves and unions ahead of and following trap permit removal of entire trap from line.

Fig. 2—Armstrong traps have only two moving parts—the lever assembly and the bucket. Nothing much to go wrong here.

Another important consideration for getting the most from a standardization program is accessibility of the traps. Insofar as is possible, traps should be located so that they are convenient for inspection. The easier it is to locate and get at a trap, the less likelihood that it will be overlooked.

What Make of Trap? (This is the Commercial)

Obviously, a trap standardization program shows the best results when the make of trap selected is the one that gives the best service. Naturally, we think the make should be Armstrong and fortunately a lot of trap users agree. Here are some of the advantages of standardizing on Armstrong that have been pointed out by these users:

1. *Armstrong traps work.* They don't leak steam and they do discharge condensate and air as fast as they reach the trap. And they work with any return system.

2. *Armstrong traps aren't "prima donnas."* They need no special care or coddling. Valve and seat are hardened chrome steel. Lever assembly and bucket are stainless steel and these are the only moving parts.

3. *Armstrong traps aren't "orphans."* You can *always* get parts and service from nearby Factory Representatives and stocking distributors.

4. *Armstrong traps are guaranteed.* If you're not *completely* satisfied you can return the traps for refund of purchase price.

More Information

The 44-page Steam Trap Book (free on request) gives a lot more facts on trap selection and installation. Call your local Armstrong Representative or write **Armstrong Machine Works, 8523 Maple St., Three Rivers, Michigan.**

ARMSTRONG STEAM TRAPS

For more data on advertised products, use Readers' Service Cards, last page.

NO LEAKAGE...

You're looking at the newest thing in valves . . .

STOCKHAM'S NEW WEDGEPLUG* "O-SEAL" VALVE

Two Teflon** "O" rings in the plug give constant vapor-tight shut-off . . . to give you double assurance of double savings on operating and maintenance costs.

NO LUBRICATION!...

HOW TEFLON "O" RINGS WORK The two Teflon "O" rings are inserted in dovetail grooves machined on the face of the plug. These "O" rings seat on the raised body seats when the plug is in closed position.

CONSTANT VAPOR-TIGHT SHUT-OFF This sealing effect of the "O" rings gives absolute shut-off in all cases—shut-off that remains permanently "bubble tight." The Teflon "O" rings are chemically inert, practically frictionless, and will not cold flow.

TESTS PROVE POSITIVE SHUT-OFF

Hundreds of tests of this new valve in all types of services have failed to make it leak. Performance has been remarkable. In every case, the valve held "bubble tight" because of the pressure seal effect of the "O" rings.

OTHER OUTSTANDING ADVANTAGES

Non-Lubricated—no costly maintenance necessary • Provides Double-Block and Bleed in most services • Quick, Easy Operation—won't stick or bind • Double Seating for Double Safety—Ground metal-to-metal seat provides shut-off in case fire burns out "O" rings • No Product Contamination • Protected Seats

RECOMMENDED USAGES Stockham's new "O-Seal" is recommended for all general purposes—air, gas, water, steam, propane, hydrocarbons, etc., as well as for hard-to-hold services. Recommended for temperatures from minus 300 F to 400 F and not exceeding 720 psi.

Available in carbon and alloy steels, 2" - 12" sizes, 150 and 300 lb. pressures. Three port openings—40%, 70%, full round-wrench, handwheel, gear, and motor operated.

*Patented
**Teflon DuPont Trademark

STOCKHAM'S NEW WEDGEPLUG "O-SEAL" VALVE

Call Your STOCKHAM Distributor or Sales Representative for complete details, or write today for the new brochure on the Wedgeplug "O-Seal."

Stockham makes a **BETTER** *valve...for* **EVERY** *job!*

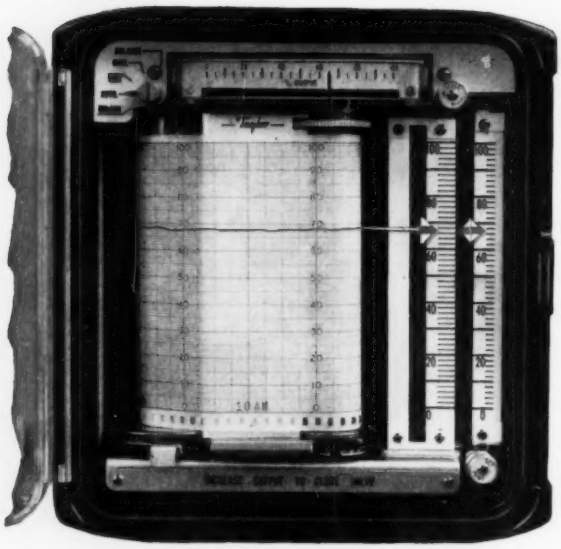
WEDGEPLUG VALVE COMPANY Division of →

STOCKHAM VALVES *and* FITTINGS

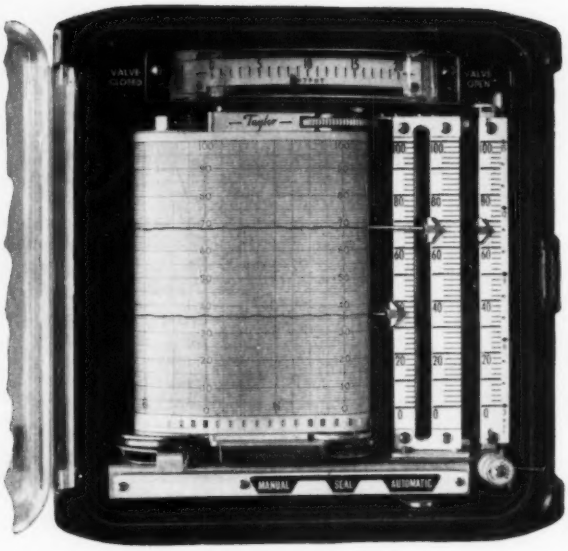
General Offices and Plant — 4003 North 10th Avenue, Birmingham 2, Alabama

CAST IRON-MALLEABLE PIPE FITTINGS • BRONZE, CAST IRON, DUCTILE IRON, CAST AND FORGED STEEL VALVES

All Process Engineers: Compare Features of the New Taylor Electronic AC or DC Recorder and the exceptional TRANSCOPE* Pneumatic Recorder (90-J)



701J AC or DC Electronic Recorder



90J Transcope Pneumatic Recorder

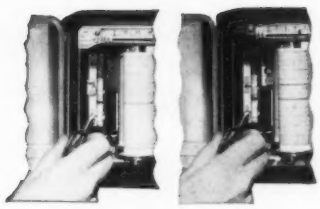
NEVER BEFORE SO MANY FEATURES IN SO LITTLE PANEL SPACE

1. Unconfused Readability. Because chart record, pen and set-point are side-by-side, whether electronic or pneumatic. Target-type pens and pointers are easiest of all to see, even at a distance. The 4″ chart reads from left to right—like a newspaper—on rectilinear coordinates. Thus, operators are encouraged to make frequent readings . . . and they make fewer mistakes because all pertinent data is lined up.

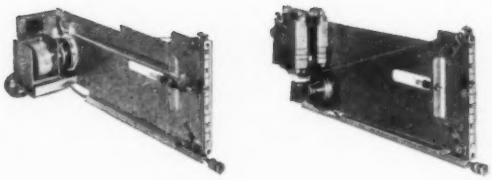
*Reg. U.S. Pat. Off.

LOOK TO TAYLOR FOR

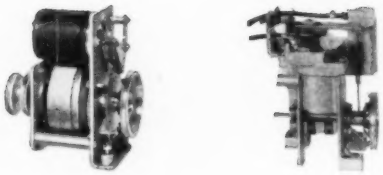
Taylor Instruments



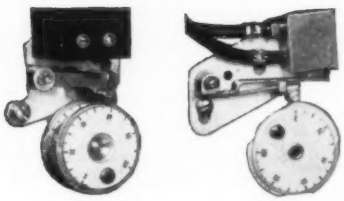
2. Front Adjustments—a Taylor 'first'. Controller response adjustments are quickly and easily made from the front, where results can be watched, on both Electronic (left) and Pneumatic (right) instruments. You can visualize immediately all pertinent process information—record, pen and set point.



3. Plug-in Set Point Transmitters, parallel to and exactly matching chart range, permit comparison without confusion and accurate adjustment of the control point. Separate set point transmitter enables you to stay on fully automatic control, even when recorder slide is removed.



4. Powerful Servo Motors give more precise pen positioning than ever before. More accurate records. Unmatched threshold sensitivity. Unparalleled power permits use of process alarms, new inking system and elimination of flimsy linkage.



5. Built-in Process Protection. Integral heavy duty alarms can be standard or hermetically sealed for Class I, Group D, Div. 2. Each cam may be set for high or low level or high-low. Contacts can be normally open or normally closed. "Memory Pointers" indicate *magnitude* beyond the alarm setting of the process variable. Cost is substantially less than conventional systems.

See your Taylor Field Engineer or write for appropriate Bulletin.
Taylor Instrument Companies, Rochester, N. Y., and Toronto, Ontario.

VISION • INGENUITY • DEPENDABILITY

MEAN ACCURACY FIRST

For more data on advertised products, use Readers' Service Cards, last page.

Tuffy Tips —on safe use of Slings and Hoist Lines

Safety Council Cites Factors In Lifting Injuries

The National Safety Council points out that nearly a fourth of all compensation cases are the result of unsafe handling methods or conditions, and lists the following as factors contributing to handling injuries:

"(a) Handling loads that are too heavy; (b) lifting or lowering with the back muscles instead of the leg muscles; (c) handling load with an insecure grip and failing to watch where hands are placed; (d) handling without sufficient help or failing to use mechanical equipment; (e) handling before getting a firm footing; (f) lifting or lowering with a jerking, twisting movement of the body, or when the body is in an awkward position."

Maintenance Tips for Hoisting Equipment

(1) Be sure crane and hoist controls are in proper working order. Don't use equipment that hasn't been tested recently.

(2) Inspect hitching equipment before it is used. Recheck after use.

(3) Remove hitching equipment not in use from hooks, hoists and loads. Don't allow it to remain loose.

(4) Store slings systematically when they're not in use. Don't let them lie around helter-skelter. They may be damaged between lifts.

Proper Sling Fittings Assure Greatest Safety and Efficiency

Fittings used on Tuffy Slings are of the most improved types and are factory-fitted on the Tuffy Sling you order. Or, if you prefer, you can fit them in your rigging loft. Shown here are two of these Tuffy Sling fittings.

Newco Gripper Sling Hook:

Fitted with a spring that bears against the sling. This holds slide hook at any position on sling, thus preventing it from sliding down to the sling eye each time it is unhitched. Easily positioned for each new load. Hook readily chokes into position when load is applied.

Sliding Hook

The smoothly rounded saddle slides on the sling leg with minimum wear to tighten on the load. Made of extraordinarily tough manganese steel to afford an ample factor of safety on rated loads. Designed with steel distributed in relation to stress lines.

Tuffy Hoist Line: Perfect Team Mate for Tuffy Slings

Tuffy Hoist Line is a special rope construction for use on all types of overhead cranes, derricks and clamshells. It has the right combination of strength, flexibility and toughness for greatest safety and longest life in its wide range of uses.

See Your Tuffy Distributor for the Most in Sling and Wire Rope Service

Ferrule Safety is a Part of Sling Safety

The steel ferrule is applied under tremendous pressure. It holds so tight that the eye splice has 100% of fabric strength. It's smoothly tapered to meet the main body of the sling. No abrupt edges or sharp projections. The extra quality and safety of Tuffy's pressed-on ferrule is yours at no extra cost.

Tuffy Braided Wire Fabric: Successor to Wire Rope in Slings

The secret of the extra strength and greater flexibility of Tuffy Slings is also the secret of their greater safety. It's the exclusive, patented, machine-braided fabric. You won't find it in any other sling. It means longer sling life, easier handling and greater ability to take deadloads, shocks and impact with safety.

Kinks Can't Hurt a Tuffy Sling

One of the first rules of ordinary wire rope safety: never use a sling that has been kinked. The wires are permanently bent, damaged and weakened. Not so with Tuffy Slings. Tuffy's patented, 9-part machine-braided fabric is just about impossible to kink. And if it does, under some unusual condition, you can straighten out the kink with ease—leaving no material damage.

FREE! New Tuffy Sling Handbook

Revised and enlarged edition. Covers slings from A to Z. Gives types, dimensions, weights, rated loads, proper fittings. Even includes safety-approved standard signals used in operation of various equipment. Send for your free copy now. Address **Union Wire Rope Corporation, 2284 Manchester Ave., Kansas City 26, Mo.** Specialists in high-carbon wire, wire rope, braided wire fabric and stress relieved wire and strand.

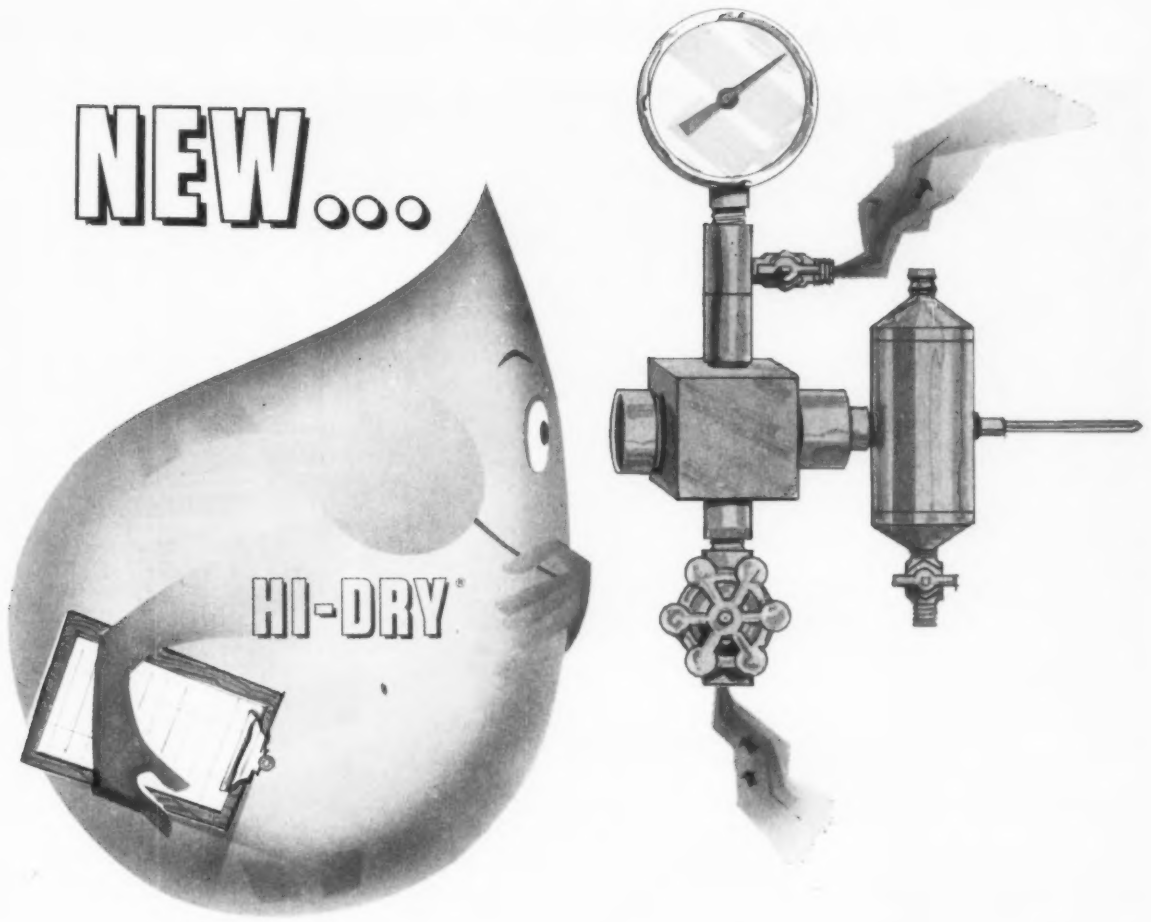
UNION Wire Rope

S-3

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division • The National Supply Company
Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Southwest Steel Products

New steels are born at Armco



Get extra dew point depression in natural gas with

HI-DRY® JEFFERSON CHEMICAL'S NEW LIQUID DESICCANT

HI-DRY® brand liquid desiccant, a new, specially prepared tetraethylene glycol concentrate, is now available to give you the extra dew point depression so often needed in dehydration of natural gas by the conventional glycol absorption process. Proved by extensive field tests, the composition of HI-DRY permits higher temperatures of reconcentration to be used without the danger of decomposition. Because of this increase in thermal stability and suitability to higher degrees of reconcentration, HI-DRY gives you greater efficiency in the dehydration of natural gas.

HI-DRY liquid desiccant is just one of a complete line of Jefferson chemicals available for sweetening and dehydration. An extensive background of experience in these processes is at your disposal. For additional information contact your local Jefferson representative, or our technical service staff at 1121 Walker Avenue, Houston 2, Texas.

JEFFERSON CHEMICAL COMPANY, INC.

HOUSTON • NEW YORK • CHICAGO • CLEVELAND
CHARLOTTE • LOS ANGELES

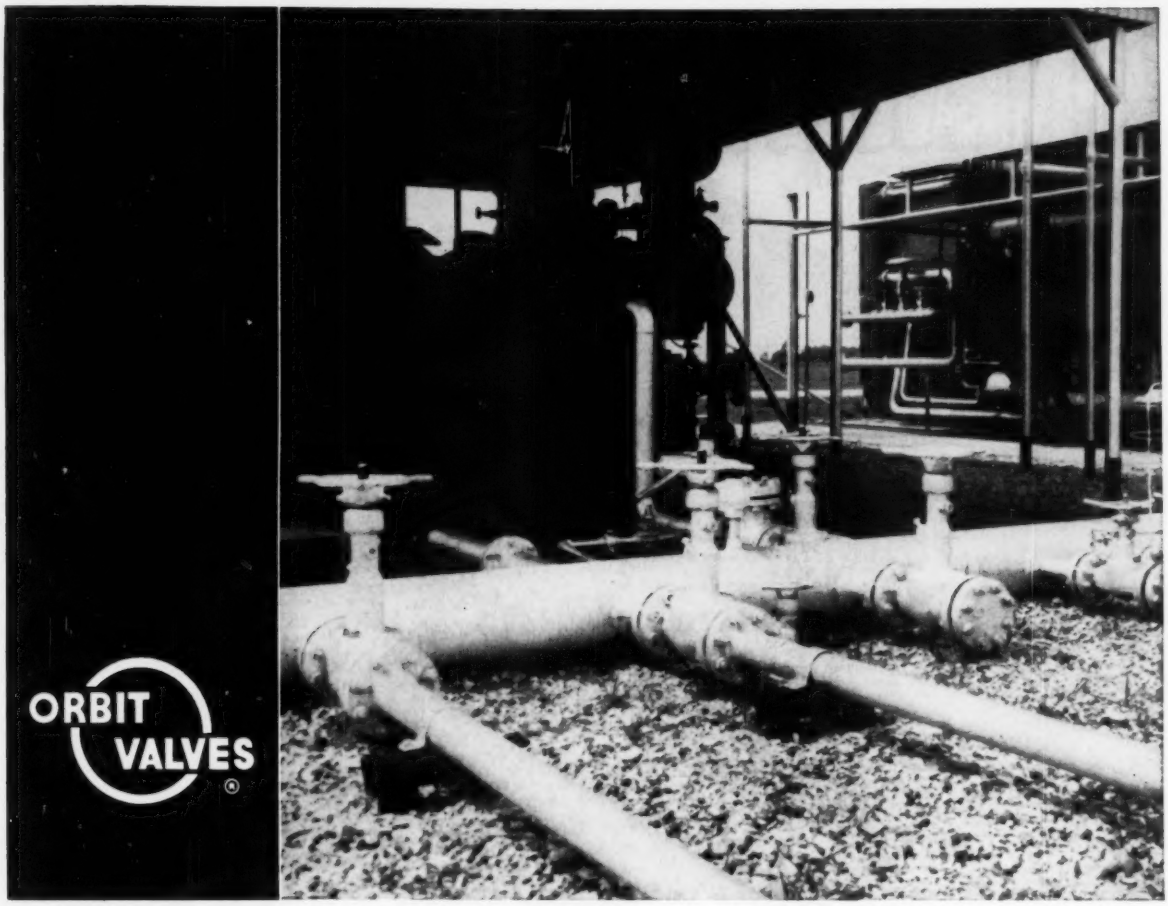
Ethylene Oxide, Glycols, Dichloride • Ethanolamines • Morpholine • Piperazine
Polyethylene Glycols • Nonyl Phenol • SURFONIC® Surface-Active Agents
Ethylene Carbonate and Propylene Carbonate • Caustic Potash • Caustic Soda
Soda Ash • Sodium Bicarbonate

Essential Chemicals From Hydrocarbon Sources

127

For more data on advertised products, use Readers' Service Cards, last page.

QUALITY AND RELIABILITY AT WORK



ORBIT FORGED STEEL VALVES ARE NON-LUBRICATED

and built for continuous heavy-duty service

Orbit valves shown in picture at top are installed in compressor discharge service. This is a tough service where velocities and vibration would play havoc with most valves — but not with Orbit valves, because they are built to withstand continuous heavy-duty service.

WRITE FOR CATALOG 58-B COVERING ASA CLASS VALVES OR CATALOG 58-A COVERING PRODUCTION VALVES.

ORBIT VALVE COMPANY

P. O. BOX 699, TULSA, OKLAHOMA, Phone LUther 4-4761, TWX TU 925
WAREHOUSES: HOUSTON, TEXAS, 407 Velasco, CApitol 8-6623, TWX HO 115; ODESSA, TEXAS, 402 West County Road, FEderal 7-2263, TWX ODESSA TEX 8706; LAFAYETTE, LOUISIANA, 3111 Cameron St., CEnter 4-3326; CASPER, WYOMING, 414 South Elm Street, Phone 2-1324; EDMONTON, ALBERTA, CANADA, 7119-104th St., Phone 391-283. WEST COAST REPRESENTATIVES: Charles Lowe Company, 383 Fourth Street, San Francisco, Calif.; Marshall E. Niedecker Company, 2785 Cherry Ave., Signal Hill, Calif. CANADIAN REPRESENTATIVES: T. R. Pickford & Company, Ltd., Calgary, Alberta, 309 7th Avenue West; Amherst 2-7371. EXPORT REPRESENTATIVE: New York 36, N. Y., 500 Fifth Avenue, BRyant 9-2236.

Items of Interest to the Processing Industry

WOLVERINE TUBE

PUBLISHED BY WOLVERINE TUBE

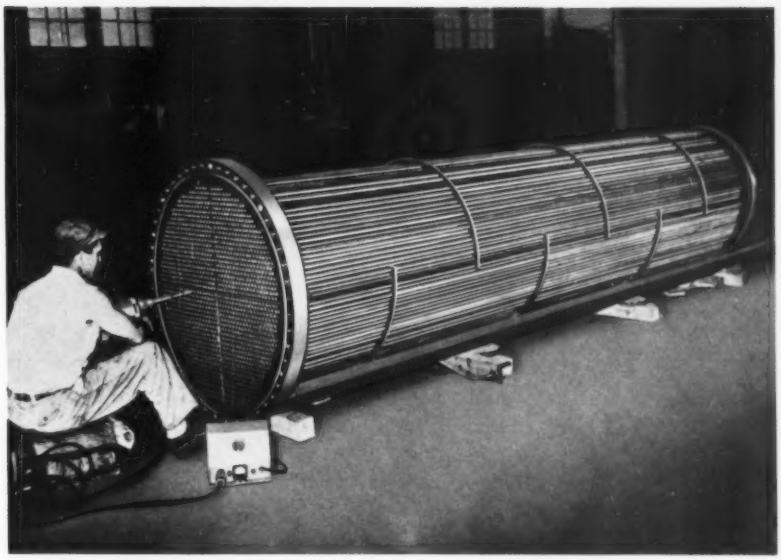
SOUTHWEST CHEMICAL COMPANY SAVES $50,000 BY USING WOLVERINE TRUFIN® TYPE S/T

BY ERNEST DODD

Fifty thousand dollars is a lot of money . . . yet this is the amount saved by a large southwestern chemical company when it used Wolverine Trufin Type S/T condenser tubing to solve a specific heat transfer problem.

In this case, refinery engineers desired to increase the throughput of a given operation. However, a survey revealed that to get the necessary increase would require doubling the heat exchanger surface.

This would have required another heat exchanger as large as the existing unit along with additional space and structure. This naturally involved considerable money.



However, a study of the problem revealed that by redesigning the existing bundle and retubing with Wolverine Trufin Type S/T — the original, integrally-finned condenser tube — the need for the additional equipment would be eliminated. This was done using Trufin Type S/T in pure nickel form. Savings in time, labor and materials have been estimated at more than $50,000.

This is but another in the long list of authenticated examples of the outstanding heat transfer job that Wolverine Trufin Type S/T is doing throughout American industry. Why not get the complete story for yourself? Write for the Trufin Catalog or talk to one of Wolverine Tube's highly-trained heat transfer sales specialists. Their names, addresses and telephone numbers are listed on the reverse side of this page.

ADMIRALTY TRUFIN OFFERS 13% BOOST IN SURFACE AREA

Does your heat transfer operation require Admiralty condenser tube in integrally-finned form? *Then here's good news for you!*

Now — thanks to Wolverine Tube's continuous research program — it is possible to obtain a 13% increase in outside surface area of Trufin Type S/T Admiralty condenser tube.

This increase is made possible through the development of a readjusted fin contour that permits Admiralty Trufin to compare favorably in outside surface area with copper Trufin Type S/T.

As a result, shell and tube units, where Admiralty Trufin Type S/T is used, can gain a significant increase in outside surface area which in turn means a significant increase in total heat duty handled or a decrease in the size of the exchanger or both.

This is a point well worth remembering if you are about to retube existing units or are considering the design of new equipment.

TRUFIN TYPE S/T IDEAL FOR USE IN NEW OR OLD UNITS

Wolverine Trufin Type S/T is finding ever increasing acceptance in the chemical, petro-chemical and petroleum refining fields . . . for use both when retubing existing equipment or designing new units.

Retubing an existing heat exchanger can be accomplished, in many instances, simply by directly substituting Trufin Type S/T for prime surface tube. Because its integral fins give it greater outside surface area Trufin packs more heat transfer surface into a given space thus steps up the capacity of existing units.

When new equipment is being designed Trufin Type S/T permits the design of smaller, more effective units with a direct saving in materials, time and labor. Trufin Type S/T is widely used in naphtha condensing, butylene condensing and lube oil cooling—is particularly effective in handling light hydrocarbons.

Wolverine Trufin is available in Canada through the Unifin Tube Division, London, Ontario, Canada.

NEED HELP WITH HEAT EXCHANGER PROBLEMS?
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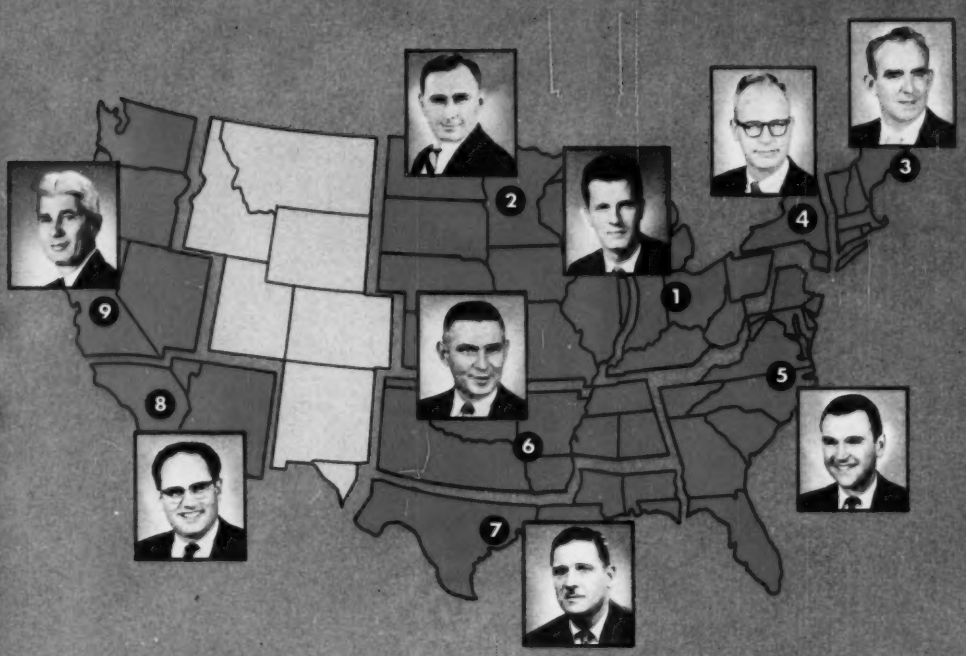

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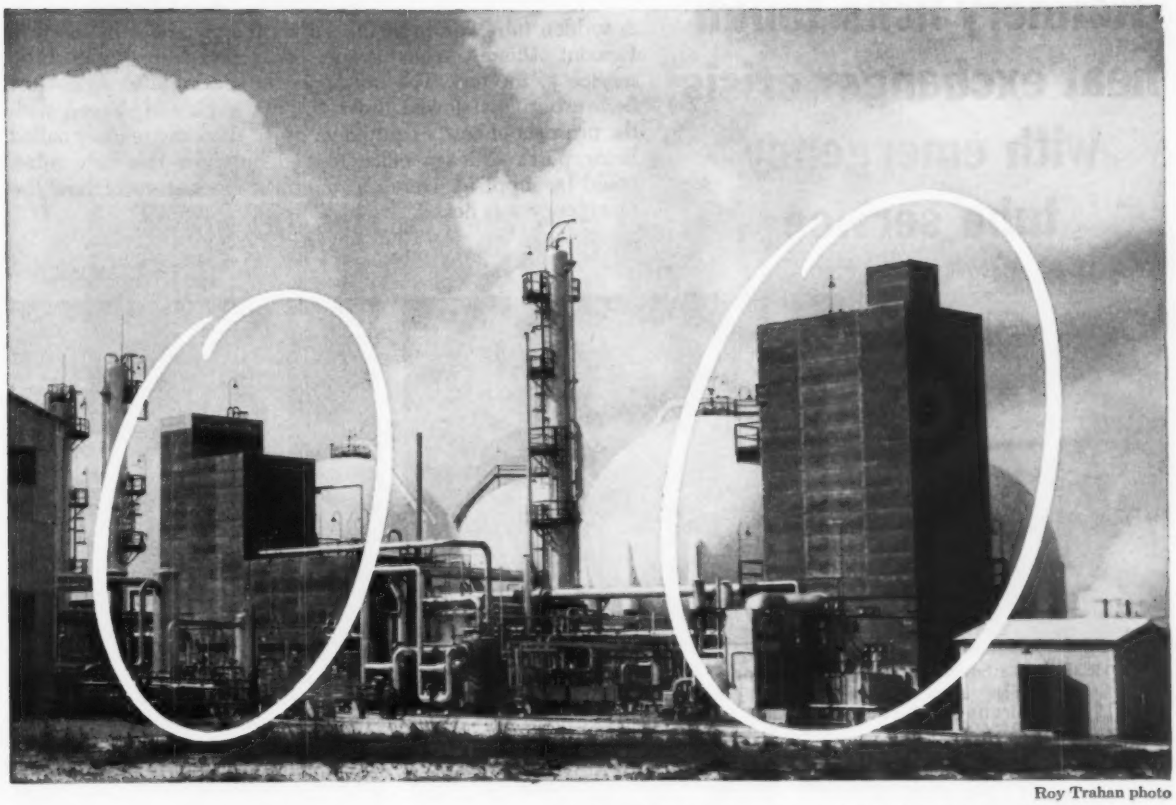

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Refinery licks tough heat exchanger crisis with emergency tube service

A sudden tube failure at the Pure Oil Company's Refinery in Lemont, Illinois, recently put Bridgeport's condenser tube service to the test. The failure hit on Friday afternoon—just before business slowed down for the week end. Faced with the prospect of costly equipment down time, the refinery called Bridgeport's Chicago office to find out how fast new tubes could be supplied. Here's a round-the-clock story of how the emergency was licked.

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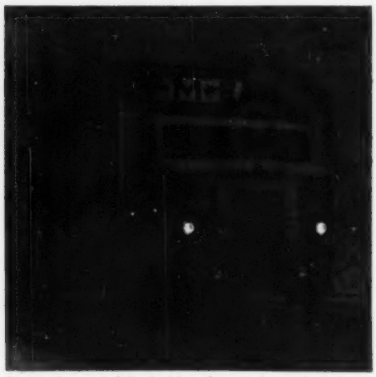
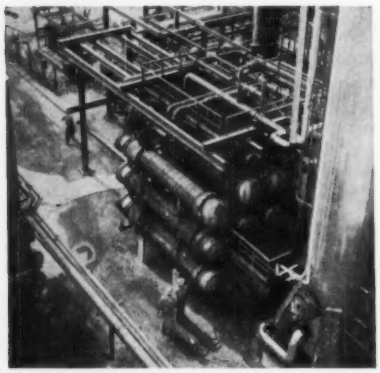
Friday, 3:30 P.M.: Sudden change in customer's needs makes immediate delivery of tubes imperative.

Friday, 4:15 P.M.: Chicago office checks through coast to coast network of Bridgeport warehouse stocks. Locates tubes at Beaumont, Texas.

Friday, 4:30 P.M.: Special night shift at Beaumont is put on job to cut tubes to special lengths and pack for shipment.



Saturday, 4:00 A.M.: Special truck leaves Beaumont, Texas, with order for Pure Oil Refinery in Lemont, Illinois.



Sunday, 11:30 P.M.: Truck arrives at Lemont Refinery with 900 Admiralty tubes, ready for repair work to start Monday morning.

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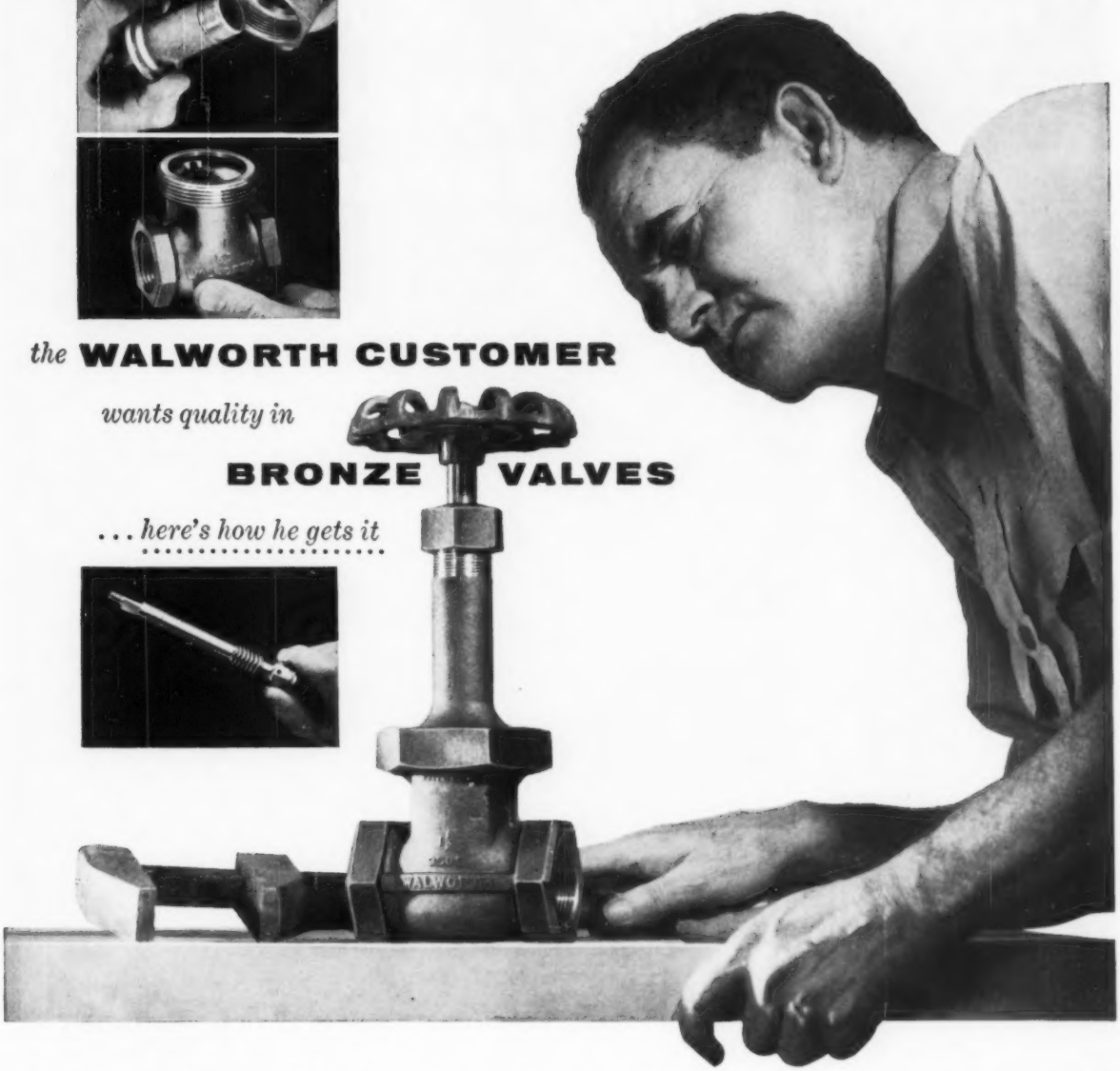

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Professional Status

To the Editor:

My hearty congratulations on Dr. John McKetta's timely and thorough presentation on "What Price Professionalism?" which appeared on Page 193 of your February issue. The analysis of the situation covers new thoughts and confirms old ones, all indicating that we (engineers) are the profession—it is no better than we make it. Our problems seem to be centered again with the individual, his appreciation of what has been done, is being done, and needs to be done to achieve true professional status.

I'd like to see every college senior in engineering, as well as graduates, have an opportunity to read your "professional" presentation.

Lake Jackson, Texas E. E. Ludwig

Asks Reference

To the Editor:

I read the article "How To Separate Xylenes for Profit" (November 1958) PETROLEUM REFINER Page 195 and I would be very grateful if you could inform me about the method the author used to analyze the mixtures of xylenes in infrared and if possible to indicate the article in which this method is described.

Ing. Colomba Lupu

ICECHIM—Bucarest, Hungary

Editor's Note: *The authors have indicated that the desired information may be found in Analytical Chemistry, Vol. 30, Part I, No. 4, Page 550, 1958 in a paper by D. M. Frankel and C. E. Johnson, Stauffer Chemical Co., Torrance, Calif.*

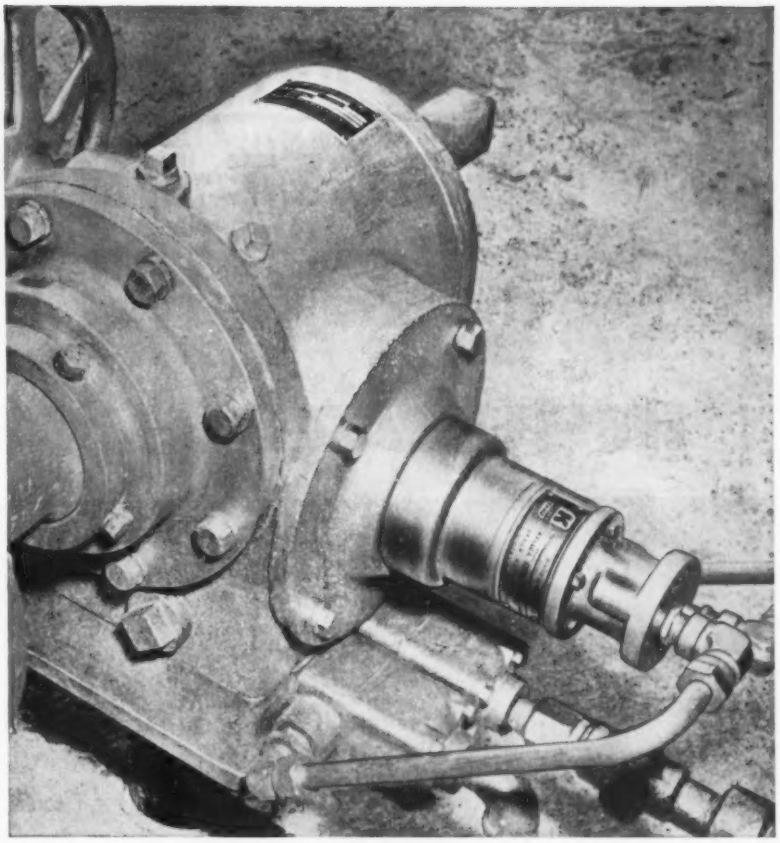
Erratum

To the Editor:

Unfortunately the abscissa on Figure 1 of the article entitled "Remove and Recover Acetylene," March 1959 PETROLEUM REFINER, page 210 was mislabeled by me. It should read "moles of acetylene per mole of solvent" rather than "x, mole fraction of acetylene." This error was not cumulative and does not influence the other figures or calculations.

Could you arrange to publish an Erratum to revise the abscissa on Figure 1?

Texas City, Texas W. H. Stanton



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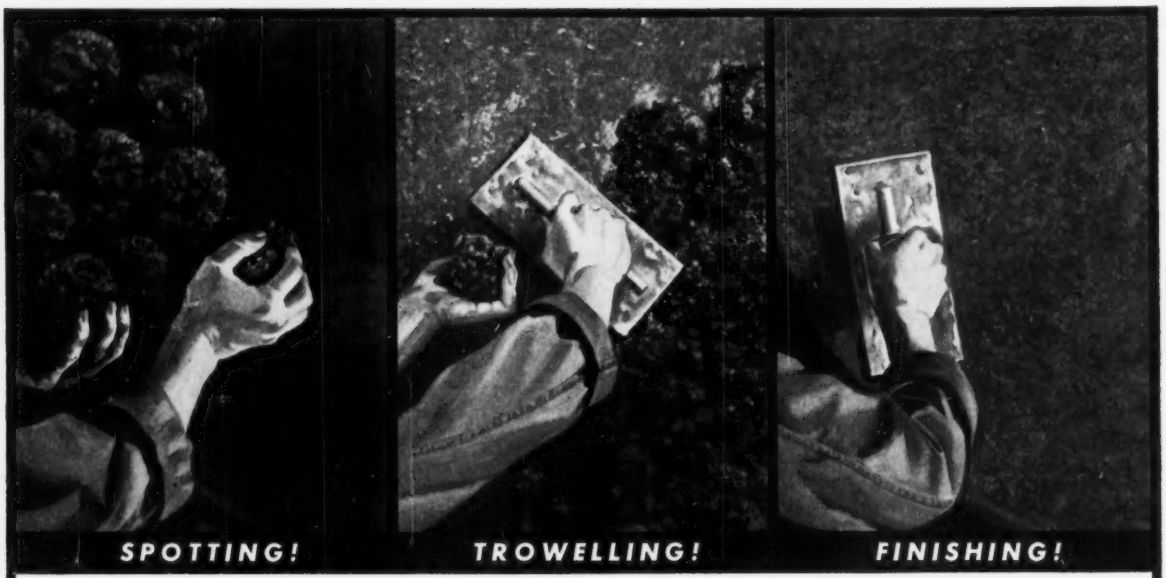

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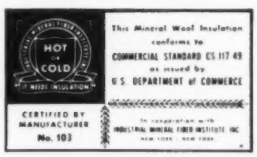

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A PETROLEUM REFINER SPECIAL REPORT

Natural Gasoline

What's happening in the natural gasoline industry? New developments are taking place in processes, maintenance, training and operations. You'll want to check these developments in this report:

Kerosine as Absorption Oil—How Good? 144

Process Natural Gas by Permeation 147

Flexible Compressors with Piston Pockets 151

Operator's Handbook for Gasoline Plants 155

At the NGAA annual meeting, forums featured new ideas in plants, computers and manpower appraisal. You'll find the highlights in these articles:

Giammarco-Vetrocoke Processes 161

Setting Up Preventive Maintenance 169

Computing Convergence Pressure 172

Appraise Personnel by Setting Goals 174

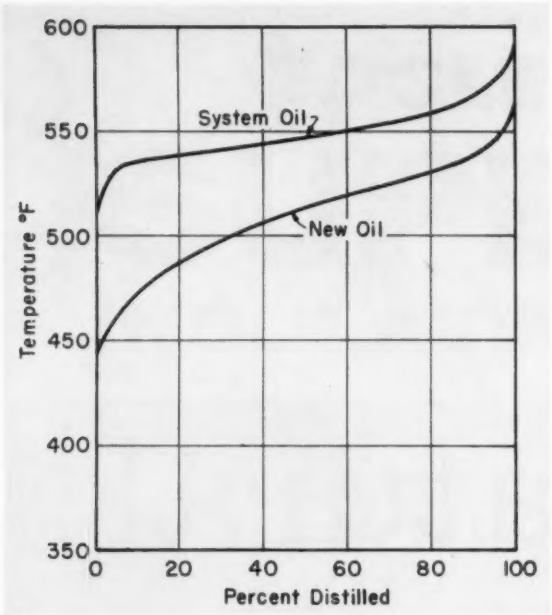

FIGURE 1—ASTM distillation curves for gas-oil system: Lighter components were lost gradually, not immediately.

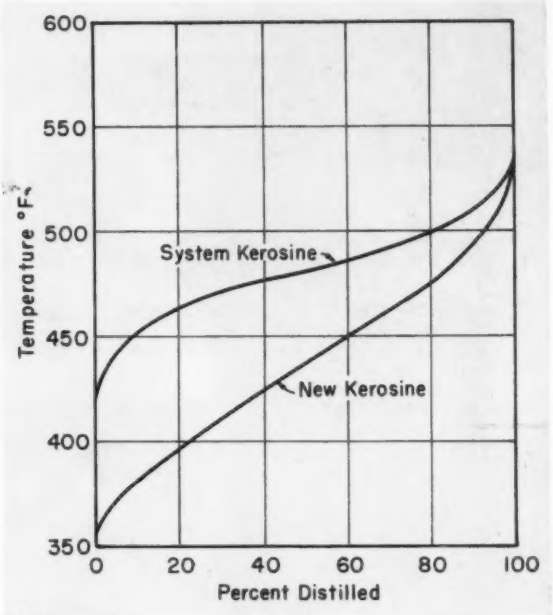

FIGURE 2—ASTM distillation curves for kerosine system: This system curve is also higher than the charged product.

Kerosine as Absorption Oil—How Good?

Most plants should lower molecular weight of absorption oil. Here's how kerosine increased production and circulation in one plant

E. A. Harper
Phillips Petroleum Company
Bartlesville, Okla.

"YOU CAN break production records and cut costs per gallon by simply ordering commercial kerosine as the absorption medium for your distillation unit." This statement to many gasoline plant managers receives a startling reaction; but actual tests have proved it to be a fact for most of the gasoline plants being operated today. It is universally true for plants of older construction and too near their economic limit to justify changing to a more modern, high retention plant. Some newer units can also gain by the use of kerosine. In most gasoline plants, after the original design has been completed and the absorption oil source selected, it is assumed this is the best absorption oil. Also, if the plant meets the basic design guarantee, little attention is focused on ways of improving the extraction efficiency through changes in the absorption oil.

Your absorption oil has probably been operating satisfactory for years and under properly established conditions, based on the usual laboratory data; but what about the whole picture? For example, have you ever drawn a curve showing the simple ASTM distillation for the oil being circulated in your distillation unit? Do you know the predominant boiling range of your absorption medium?

ASTM Tests. Not long ago, it was discovered that the answers to these same questions were ones of either indecision or controversy in a gasoline plant that had been in operation for several years. It had been established, by actual analytical determinations that the molecular weight of the absorption oil being circulated was much higher than normally expected; yet, routine tests showed the plant to be operating satisfactorily. Various means were concocted to find out the reasons. The one item that produced the most usuable information was a distillation curve drawn from the ASTM distillation test. Actually, two curves were plotted—one of the original gas-oil stock being charged to the unit and one of the absorption oil being circulated in the system. Figure 1 is a reproduction of the actual curves. Take a look, as we did, at these curves.

At a first glance, it apears the distillation unit is being unsatisfactorily operated and the lighter components are being immediately lost either to the gas or the gasoline leaving the plant. This can be easily concluded from a first examination of the curves, which reveal only the heavier portions of the charged oil remain in the system. However, further examination of the operating data proved the light end losses were gradual, since the routine gravity and molecular weight tests showed a general increase throughout the operating period of the plant.

Based on this further evidence, it was concluded that small losses are sustained into the residue gas due to equilibrium, and also occur due to the operation of the stripping system. For example, the stripping action over a long period of time could produce undetectable lossess of the lighter components from the absorption oil. We believed these factors caused the high molecular weight and lower molecular weight absorption oil would be obtained only by charging a lighter base product to the distillation unit.

Why circulate oil having a lower molecular weight? Any method used in calculating the amount of hydrocarbons absorbed in a gasoline plant absorber incorporates the ratio of the mols of lean oil circulated to the mols of gas being contacted. The higher this ratio, the more products absorbed and recovered.

One means of increasing this ratio is to circulate more oil. However, in most cases, the physical limitations of the distillation unit prevent an increase in the oil circulation. Under these conditions, a definite advantage can be realized by reducing the molecular weight of the oil. This allows more mols of oil to be circulated although actually the same number of gallons of lean oil are being pumped. This increase is not in the direct ratio of the molecular weights, since the specific gravity is less at a lower molecular weight, but a substantial net increase is realized.

Several products were considered as a possible replacement for the gas-oil charge stock being used at the time. The gas-oil was in the 200 molecular weight range, but the oil in the system was in the 225 molecular weight range. One product considered had a molecular weight of about 150, but the lower section of the distillation curve was below the temperature range considered desirable. There was a considerable overlap between the light components in this product and the heavier components actually produced in the natural gasoline at the plant. It was at this point, kerosine was suggested and evaluated. The boiling range was not excessive, the molecular weight was about 175, and it had the added advantage of being readily available in unlimited quantities. Since no definite conclusions could be reached on the probable increased oil consumption and since the potential production increase was desirable, a test run was proposed.

TABLE 1—Distillation Unit Data

	Gas-Oil System	Kerosine System
Inlet Gas		
Volume (MMcfd)	100	100
Temperature, F	90	90
Pressure, psig	200	200
System Oil		
Circulation, GPM	700	700
API Gravity	39.0	41.2
Mol Wt	225	196
Moles Oil/Min	21.5	24.2
Production—GPD		
Propane	15,750	17,750
Butanes	32,820	36,600
Pentanes and Heavier	44,550	44,550

TABLE 2—Absorption Oil Costs

	Gas-Oil	Kerosine
Consumption, GPD	300	330
Delivered Price, ¢/gallon	11.5	13.5
Total Cost, $/Day	34.50	44.55

Test Run Results. The kerosine absorption oil test was simple and consisted of substituting the gas-oil charge stock with a kerosine charge stock and replacing the oil in the distillation unit. This was done by simply charging kerosine to the unit instead of the gas-oil and removing the heavier oil from the unit. This permitted the test to proceed as fast as practical. The conversion was almost routine since few changes were noticed in magnitude and not any more than experienced during normal seasonal variations. The feed volume and the draw-off of the heavier oil were gradually reduced as the oil in the system became predominantly kerosine. This procedure was followed until the boiling point curve approached that of the kerosine charge stock.

At this point, it was definitely concluded the plant could be operated satisfactorily with kerosine as the charge medium. Only time would tell the actual increase in the volume of absorption oil being consumed, but it had been established by this time the additional quantity used was not excessive. The unit was checked very frequently at first, although it was soon realized the checking could follow the same routine previously used on the gas-oil system. This was done and control adjustments were made to maintain the desired limits. These revisions should have been put into practice much sooner but it took this test run to emphasize it.

Figure 2 shows the distillation curves for the absorption oil and kerosine charge stock one year after the initial charge of kerosine into the system. As was expected, the system curve shows a higher boiling range than does the product being charged. In fact, if the curves for the original charge stock are matched, then the product curves for the oil in the system are also almost superimposed. This was not expected. There is no definite conclusion we can reach from this but we believe it shows the molecular weight of the oil being circulated in any distillation unit will run considerably higher than the molecular weight of the oil being charged. Also, we believe it is not due to heavy product contamination from the gas but due to the gradual oil losses over an extended period.

Increased Income. Economics of the kerosine system are straightforward. The actual physical properties

of the oil circulated in the plant are shown in Table 1. The original processing data have been revised, for convenience, to a basis of 100,000 Mcfd of inlet gas. Notice the oil circulation is identical for both systems —700 gpm. However, due to the difference in the molecular weight, the moles circulated per minute are 21.5 and 24.2 for the gas-oil and kerosine systems, respectively. This is an increase in the effective circulation of 12.7 percent. In other words, we have increased the distillation unit circulation 12.7 percent without pumping any more oil. This means more production. As indicated in the table, this is an increase in the LPG production of 2,000 gpd of propane and 3,780 gpd of butane for each hundred million cubic feet of inlet gas.

To find out whether or not the changes produced here are profitable, we must examine the costs of the conversion to kerosine. The cost of the absorption oil is summarized in Table 2. Based on an increase in absorption oil consumption of ten per cent and an increase in the delivered cost of 2¢ per gallon, the added absorption oil cost is only $10.05 per day, which is much less than the value of the increased production. In some cases, other costs have been experienced but they too are usually insignificant in view of the production increase that results from the reduced molecular weight. Actually, the 10 percent increased oil loss used in the table is high since it is the maximum experienced to date for several gasoline plants that have changed to kerosine as the absorption oil charge stock.

Other Operational Features. One consideration, prior to running the test, was the effect the lighter oil might have on the pumps, heat exchangers, cooling coils and related equipment. We knew the total head required for the pumps would have to increase if the lighter oil were pumped while sustaining the same pressure drops. Other factors were considered but they did not present a potential problem, so no attempt was made to evaluate them. This was one place where we were pleasantly surprised. The pumps not only came through with flying colors, but due to the lower viscosity of the kerosine more absorption oil could be circulated in the system. This was possible due to a reduction in the pressure drop across the exchangers and no appreciable change in the heat loads. These conditions permitted an actual increase in the oil circulation of 8 percent. This permitted a further increase in the LPG production of 1,400 gallons per day of propane and 3,400 gallons per day of butane per 100,000 Mcfd of inlet gas.

One factor that requires close attention during the conversion to kerosine is the operation of the stripping and condensing portion of the distillation unit. Since more moles are being circulated, either more stripping steam or a higher still temperature is required to maintain the same degree of stripping. Also, if the oil losses are high under the original stripping operations, then additional reflux cooling must be provided. These requirements are not excessive in view of the production increase that is experienced.

Referring to Figures 1 and 2, the absorption oil in the system is of a higher boiling range than the original product charged. We think there are two reasons for this. First, the residue gas has a tendency to strip out the lighter components at a faster rate than the heavier components, due to the normal equilibrium conditions. This is expected and the quantity is dependent upon the absorber temperature and pressure. Second, the stripping of the oil in the still carries with it small amounts of absorption oil. This in turn is controlled by checking the overhead reflux on a periodic basis. Variations in this control or variations in the gas composition or volume tend to change the still conditions. These variations, without adjustments in the stripping recovery system, cause further losses of oil from the distillation unit. Thus, since both the gas and gasoline carry small amounts of the lighter oil components out of the system, the molecular weight gradually increases.

Even with a light charge stock, a long period of operation may result in a distillation unit operating with a higher molecular weight oil in the system than desirable. Under these conditions, the unit should be recharged. Or, by simply replacing the oil charge for one of a lighter molecular weight, the production would be increased. This is especially true if the plant is plagued with heavier "sludge" components that are plugging or fouling the heat exchangers and other process equipment.

Conclusions. Can kerosine help you? The easiest way to find out is to run a distillation curve on the oil being circulated in the system and estimate the molecular weight. Now compare these results with those shown in the attached charts. The molecular weight can be estimated from a correlation of ASTM mid-boiling point and the API gravity.[1]

These points will give a clue as to where you stand. Use the data obtained above and ask yourself these three simple questions:

1. Is the molecular weight above the 190-200 range?
2. Is the end point of the charge stock above 550 F.?
3. Does the plant have dirty heat exchangers, coolers, or preheaters in the distillation unit?

If you answer yes to any one of these questions, and if you are interested in making more production at your gasoline plant, you should take a look at kerosine.

LITERATURE CITED

[1]Hull, R. J. and Raymond, K., "Design and Evaluation of Absorbers," Proceedings—28th Annual Fall Meeting of CNGA, 77 (1953).

About the Author

E. A. Harper is an assistant chief processing engineer and supervisor of gasoline plant process design, Phillips Petroleum Co., Bartlesville, Okla. Holder of a B.S. degree in chemical engineering from the University of Oklahoma, he has 17 years experience in Phillips' Natural gasoline department. A registered professional engineer, Harper has been a process engineer, project engineer and process design supervisor.

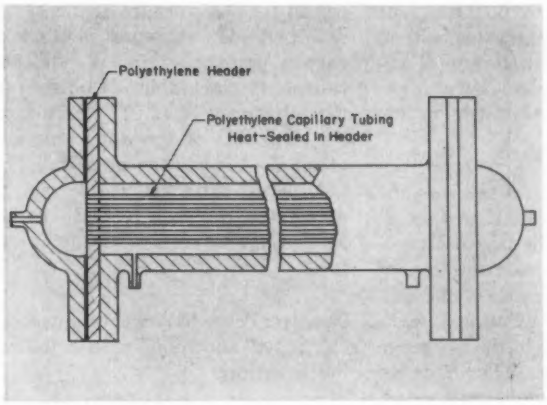

FIGURE 1—Permeation cell with polyethylene header: The set-up is comparable to a tube-in-shell heat exchanger.

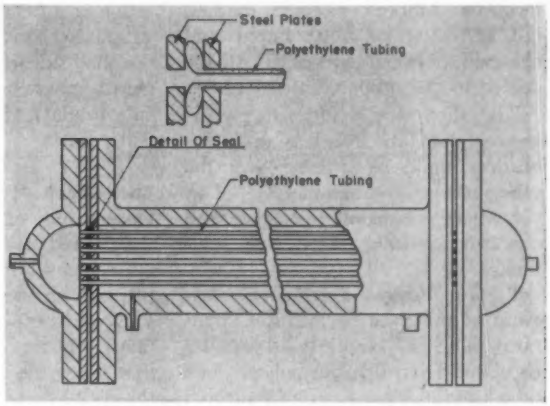

FIGURE 2—Permeation cell with steel header: The tubes were heat flared and clamped between two steel plates.

Process Natural Gas by Permeation

This study shows how effectively light hydrocarbons can be separated through polyethylene film. The cell design is comparable to a tube-in-shell heat exchanger

C. J. Walters*
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PERMEATION OF a multicomponent mixture through a nonporous film is a process somewhat resembling the common absorption-stripping cycle. Components absorb on one side of the film, diffuse to the other side and revaporize. Certain components go through this process at a faster rate than others. The driving force is pressure difference, the same as is primarily true in absorption and stripping. High pressure on one side of the film corresponds to the high pressure in an absorber and reduced pressure on the opposite side corresponds to the reduced pressure in the stripper.

The permeation process is of interest because of its physical simplicity. No circulation of an absorption medium is required. Furthermore a highly selective film can be imagined, wherein the desired components permeate at a very fast rate and the undesired components at a very slow rate or vice versa.

This study was made to see how effective permeation might be in separating light hydrocarbons. Polyethylene was selected as the film material because of its paraffinic nature and its consequent resemblance to absorption oil used in natural gasoline extraction.

A second objective of the study was to develop a permeation apparatus that would expose large surface areas of very thin film in a compact unit.

Apparatus. Several attempts to construct a permeation cell with the desired characteristics led to a design comparable to a tube-in-shell heat exchanger. The tube bundle consisted of 36 polyethylene tubes, 4 feet in length, with an outside diameter of 1.57 mm and inside diameter of 1.14 mm. The bursting pressure of this tubing was 300 psia at 75 F. The shell was made from a length of 2-inch diameter pipe.

As shown in Figures 1 and 2 two methods were used to seal the tubes in the tube sheet. In the first method the tubes were heat sealed in a thick polyethylene tube sheet. In the

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of the oil circulated in the plant are shown in Table 1. The original processing data have been revised, for convenience, to a basis of 100,000 Mcfd of inlet gas. Notice the oil circulation is identical for both systems —700 gpm. However, due to the difference in the molecular weight, the moles circulated per minute are 21.5 and 24.2 for the gas-oil and kerosine systems, respectively. This is an increase in the effective circulation of 12.7 percent. In other words, we have increased the distillation unit circulation 12.7 percent without pumping any more oil. This means more production. As indicated in the table, this is an increase in the LPG production of 2,000 gpd of propane and 3,780 gpd of butane for each hundred million cubic feet of inlet gas.

To find out whether or not the changes produced here are profitable, we must examine the costs of the conversion to kerosine. The cost of the absorption oil is summarized in Table 2. Based on an increase in absorption oil consumption of ten per cent and an increase in the delivered cost of 2¢ per gallon, the added absorption oil cost is only $10.05 per day, which is much less than the value of the increased production. In some cases, other costs have been experienced but they too are usually insignificant in view of the production increase that results from the reduced molecular weight. Actually, the 10 percent increased oil loss used in the table is high since it is the maximum experienced to date for several gasoline plants that have changed to kerosine as the absorption oil charge stock.

Other Operational Features. One consideration, prior to running the test, was the effect the lighter oil might have on the pumps, heat exchangers, cooling coils and related equipment. We knew the total head required for the pumps would have to increase if the lighter oil were pumped while sustaining the same pressure drops. Other factors were considered but they did not present a potential problem, so no attempt was made to evaluate them. This was one place where we were pleasantly surprised. The pumps not only came through with flying colors, but due to the lower viscosity of the kerosine more absorption oil could be circulated in the system. This was possible due to a reduction in the pressure drop across the exchangers and no appreciable change in the heat loads. These conditions permitted an actual increase in the oil circulation of 8 percent. This permitted a further increase in the LPG production of 1,400 gallons per day of propane and 3,400 gallons per day of butane per 100,000 Mcfd of inlet gas.

One factor that requires close attention during the conversion to kerosine is the operation of the stripping and condensing portion of the distillation unit. Since more moles are being circulated, either more stripping steam or a higher still temperature is required to maintain the same degree of stripping. Also, if the oil losses are high under the original stripping operations, then additional reflux cooling must be provided. These requirements are not excessive in view of the production increase that is experienced.

Referring to Figures 1 and 2, the absorption oil in the system is of a higher boiling range than the original product charged. We think there are two reasons for this. First, the residue gas has a tendency to strip out the lighter components at a faster rate than the heavier components, due to the normal equilibrium conditions. This is expected and the quantity is dependent upon the absorber temperature and pressure. Second, the stripping of the oil in the still carries with it small amounts of absorption oil. This in turn is controlled by checking the overhead reflux on a periodic basis. Variations in this control or variations in the gas composition or volume tend to change the still conditions. These variations, without adjustments in the stripping recovery system, cause further losses of oil from the distillation unit. Thus, since both the gas and gasoline carry small amounts of the lighter oil components out of the system, the molecular weight gradually increases.

Even with a light charge stock, a long period of operation may result in a distillation unit operating with a higher molecular weight oil in the system than desirable. Under these conditions, the unit should be recharged. Or, by simply replacing the oil charge for one of a lighter molecular weight, the production would be increased. This is especially true if the plant is plagued with heavier "sludge" components that are plugging or fouling the heat exchangers and other process equipment.

Conclusions. Can kerosine help you? The easiest way to find out is to run a distillation curve on the oil being circulated in the system and estimate the molecular weight. Now compare these results with those shown in the attached charts. The molecular weight can be estimated from a correlation of ASTM mid-boiling point and the API gravity.[1]

These points will give a clue as to where you stand. Use the data obtained above and ask yourself these three simple questions:

1. Is the molecular weight above the 190-200 range?
2. Is the end point of the charge stock above 550 F.?
3. Does the plant have dirty heat exchangers, coolers, or preheaters in the distillation unit?

If you answer yes to any one of these questions, and if you are interested in making more production at your gasoline plant, you should take a look at kerosine.

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[1]Hull, R. J. and Raymond, K., "Design and Evaluation of Absorbers," Proceedings—28th Annual Fall Meeting of CNGA, 77 (1953).

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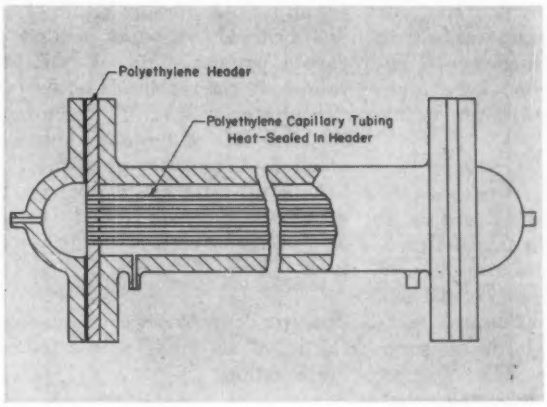

FIGURE 1—Permeation cell with polyethylene header: The set-up is comparable to a tube-in-shell heat exchanger.

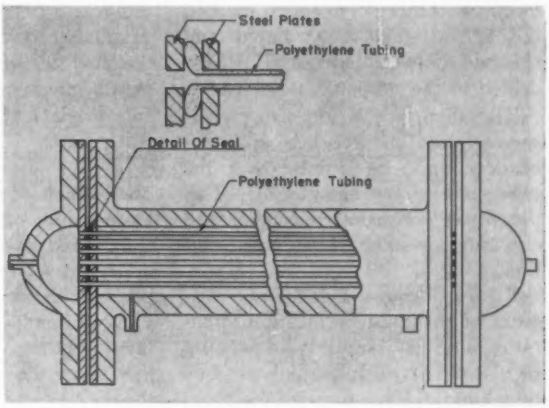

FIGURE 2—Permeation cell with steel header: The tubes were heat flared and clamped between two steel plates.

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Apparatus. Several attempts to construct a permeation cell with the desired characteristics led to a design comparable to a tube-in-shell heat exchanger. The tube bundle consisted of 36 polyethylene tubes, 4 feet in length, with an outside diameter of 1.57 mm and inside diameter of 1.14 mm. The bursting pressure of this tubing was 300 psia at 75 F. The shell was made from a length of 2-inch diameter pipe.

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second and more convenient method the tubes were heat flared and clamped between two steel plates drilled to the proper dimensions.

The shell was made somewhat shorter than the tubes so that the headers could be bolted over the tube sheet away from the shell. This permitted pressuring the tubes and checking for leaks with a soap solution.

Figure 3 shows a schematic diagram of the total permeation apparatus. The gas sample was pressure regulated through the polyethylene tube bundle. Flow through the tubes was maintained by a manually operated valve in the discharge line. The flow was too low for a flow regulator. The permeation cell was immersed in a thermostatically controlled water bath. Both permeated and unpermeated gas streams were measured with wet test meters. Samples were taken for chromatographic analysis by means of sample bulbs in the discharge gas lines.

Permeated gas could be withdrawn at either end of the shell. Tests showed the free space on the shell side was great enough to allow complete mixing of permeated gas so that no effect was observed when the point of withdrawal was changed.

Pressure on the tube side of the cell was measured by bourdon tube gauge. No back pressure was held on the shell side of the apparatus. Temperature was measured by a mercury-in-glass thermometer in the water bath.

Test Work. To start a test run, the temperature of the bath was set at the desired level. The pressure regulator was set to provide the desired pressure on the tube side of the cell. Flow through the tubes was regulated with the valve in the discharge line from the tubes. The valve on the shell side was completely opened. The apparatus was then allowed to run until analysis of several consecutive samples showed the system to be at steady state conditions.

A typical feed gas analysis is shown in Table 1. Where significant, the hexanes and heavier components and carbon dioxide were accounted for in calculating permeabilities of the other components. However, the concentrations of these components were so minute in the unpermeated gas and occurred in the chromatographic analysis in such a manner that attempts to calculate their permeabilities were abandoned.

Tests were made at 73 F., 80 F., 100 F., and 120 F. Pressure on the tube side of the cell was held at some point between 40 and 50 psig for all runs. A pressure in this range was believed optimum in that it gave a practical diffusion rate, but caused no observable plastic flow of the tubes even at 120 F. Pressure on the shell side of the apparatus was taken as barometric pressure. The volumetric ratio of residue gas to permeated gas was varied over a wide range at each of the temperatures.

Results. Permeability constants were calculated according to the following equation:

$$P_i = \frac{Q'_i \cdot t}{A \cdot \Theta \cdot (y_i p - y_i' p')}$$

where,

P_i = Permeability constant of component, i, $\frac{\text{cc at 60 F. and 1 atm.} \cdot \text{cm}}{\text{cm}^2 \cdot \text{cm Hg} \cdot \text{sec}}$

Q'_i = volume of component i permeated, cc at 60 F. and 1 atm

t = film thickness, cm

A = film area, cm^2

Θ = time of permeation, sec

y_i = average mole fraction of component i in high pressure stream.

y_i' = average mole fraction of component i in low pressure stream.

p = total pressure of high pressure stream, cm Hg

p' = total pressure of low pressure stream, cm Hg

The area, A, was calculated as the logarithmic mean of the inside and outside areas of the tubes. The mole fraction, y_i, was taken as the arithmetic average of the mole frac-

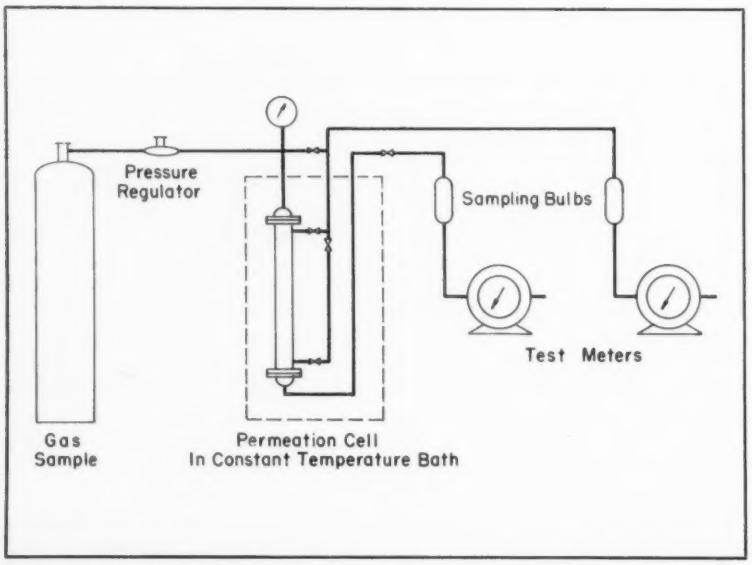

FIGURE 3—Schematic diagram for permeation apparatus. Gas sample was pressure regulated through the tube bundle.

TABLE 1—Typical Feed Gas Composition

Component	Mole Percent
Methane	83.48
Ethane	8.58
Propane	3.88
Isobutane	.54
Normal butane	1.13
Isopentane	.42
Normal pentane	.34
Hexanes and heavier	.63
Carbon dioxide	1.00
	100.00

TABLE 2—Permeability Constants

	Permeability Constant cc (1 atm & 60F.)—cm / cm^2—sec—cm Hg x 10^7			
Temperature (F)	73	80	100	120
Component				
Methane	0.58	0.75	1.23	1.84
Ethane	0.99	1.55	2.78	4.43
Propane	1.22	1.98	4.16	6.72
Isobutane	0.92	1.69	3.41	5.38
Normal butane	1.65	3.27	7.93	12.98
Isopentane	1.69	3.85	8.64	13.67
Normal pentane	2.44	6.30	16.28	28.43

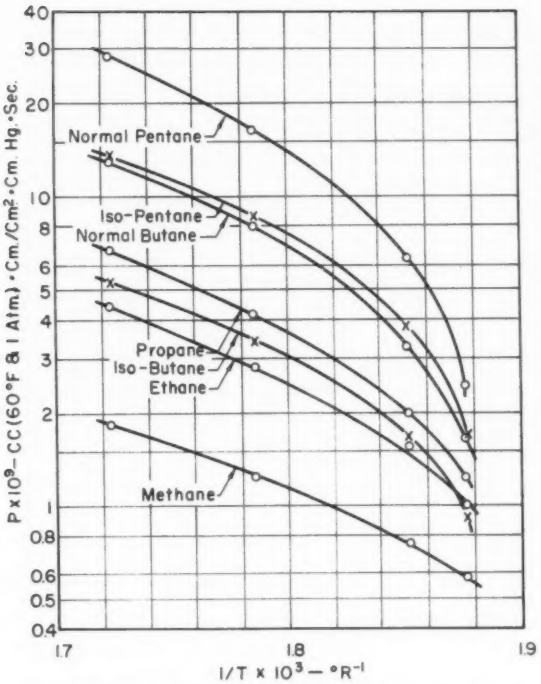

FIGURE 4—Permeability constants versus reciprocal of temperature. For methane, almost a straight line.

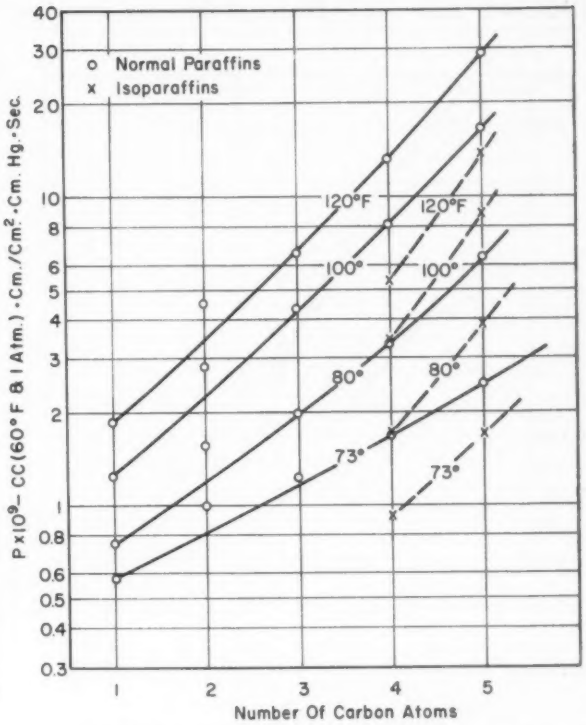

FIGURE 5—Permeability constant versus carbon number. Variation between normal and iso compounds is seen.

tion of component i in the feed gas and the residue gas.

Table 2 gives the permeability constants calculated for methane through normal pentane. The constants are the average from a number of runs at each temperature. Variations in the ratio of residue to permeated gas did not appear to influence the value of the constants.

Theoretically the logarithm of the permeability constant is directly related to the reciprocal of the absolute temperature.[1] A plot of the data in this form is shown in Figure 4. Only methane gives approximately the theoretical relationship.

In Figure 5 the permeability constants are plotted against the carbon number of the component. The variation between normal and iso compounds is readily observed. Ethane constants are all approximately 20 percent above the smooth curve drawn through the points for the other normal components. It is believed that experimental error cannot account for this deviation.

Figure 6 shows methane and ethane permeability constants compared with literature values for carbon dioxide.[2] Methane tends to have about the same slope as carbon dioxide, illustrating typical behavior of light gases. Ethane on the other hand shows the nonlinear relationship that occurs to a still greater extent as the molecules become heavier.

Permeation rates are directly related to permeability constants for a film if given dimensions and a given partial pressure difference. Table 3 shows permeation rates in moles per day for a film of 1,000 square feet and 0.01 cm thickness. Partial pressure difference is taken as 50 psi in each case. The extensive surface area that would be required for most commercial separations is clearly shown by this table.

TABLE 3—Permeation Rates

Film Area = 1000 sq. ft.
Film Thickness = 0.01 cm (0.00394 in.)
Partial Pressure Difference = 50 psi

	MOLES/24 HOURS			
Temperature (F)	73	80	100	120
Component				
Methane	0.112	0.145	0.238	0.356
Ethane	0.191	0.230	0.537	0.856
Propane	0.236	0.383	0.804	1.30
Isobutane	0.178	0.327	0.659	1.04
Normal butane	0.319	0.632	1.53	2.51
Isopentane	0.327	0.744	1.67	2.64
Normal pentane	0.472	1.22	3.15	5.50

Theoretical Separation. To demonstrate the theoretical effectiveness of permeation through polyethylene in separating the light hydrocarbons, calculations were made in which the pressure ratio across the film was assumed to be infinite. In practice this condition could be approached by evacuating permeated gas as it vaporizes from the film, or by maintaining a very high pressure on the feed gas.

No mixing was assumed on the high pressure side of the film, but complete mixing was assumed on the low pressure side. This is approximately the process expected in the tube-in-shell type apparatus. Permeability constants at 120 F. were used.

Figure 7 shows the results of these calculations for a mixture of methane through normal pentane. The composition of permeated gas is plotted as a function of the ratio of moles of permeated gas to moles of feed gas. At a ratio of 1.0, no residue gas is withdrawn, that is, the feed gas is retained in the permeation cell until it all permeates through the film. Consequently, the composition at this ratio corresponds

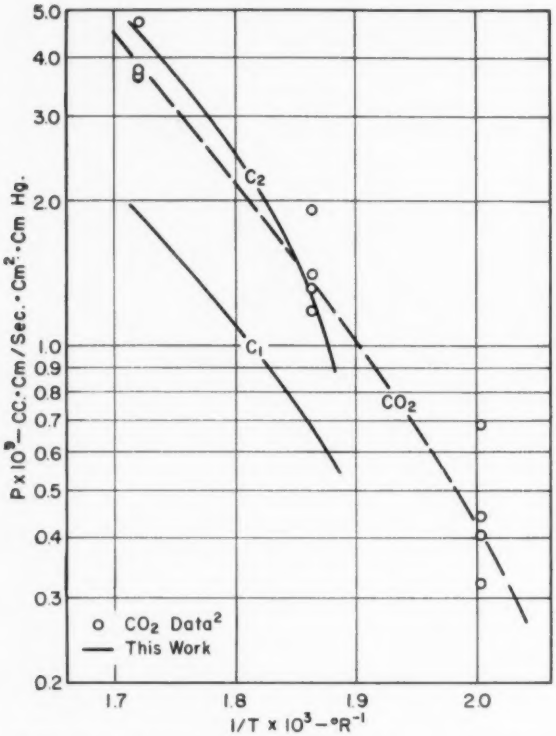

FIGURE 6—(left) How methane and ethane permeabilities compare with carbon dioxide.

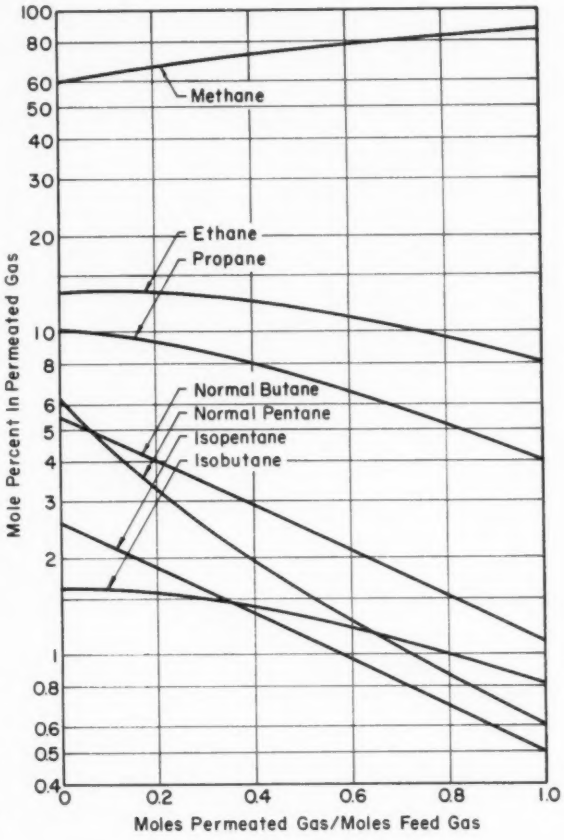

FIGURE 7—(right) Theoretical separation at 120 F. with infinite pressure ratio.

to the feed gas composition. At a ratio of 0.5, residue gas is withdrawn at a rate that matches the permeation rate. As the ratio approaches zero, residue gas is withdrawn at such a high rate that only an infinitesimal amount of feed gas can permeate. A permeation ratio approaching zero gives the highest degree of separation.

It is seen that when 20 mole percent of the feed gas is permeated, the concentration of propane and heavier components goes from 7 percent in the feed to around 20 percent in the permeated stream.

For comparison, 20 percent condensation of the gas would give a liquid containing around 30 percent propane and heavier components. However, a low temperature process would be required. At a pressure of 500 psia, a temperature of around —90 F. would be necessary to effect the partial condensation.

Conclusions. The results of the study show that appreciable separations can be obtained by permeating mixture of light hydrocarbons through polyethylene. The use of small diameter, thin-walled tubing permitted a highly satisfactory method of mounting large quantites of unsupported film in a small volume.

A multicell system with recompression between the stages could be designed to give any desired degree of separation. The design calculations for such a system handling a multicomponent mixture become so complex that for practical solution a digital computer would be required. However, until these calculations are made so that costs can be estimated, the economic attractiveness of the permeation process cannot be satisfactory compared with that of present separation processes.

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[2] Brubaker, D. W., Kammermyer, K., and Asburn, J. O., Ind. Eng. Chem., 46, 733 (1954).

About the Author

Dr. C. J. Walters is an engineer with Arabian American Oil Co., Dahran, Saudi Arabia, where he works in the planning of future processing and refining facilities. He was in oil field research with California Research Corp. from 1951-57, and served as project leader of the Natural Gasoline group at the company's La Habra laboratory. He joined Arabian American in 1957 and is presently with the Planning division, General Office Engineering department. Walters has a B.S. degree in chemical engineering from Wayne University and a Ph.D. degree in chemical engineering from Purdue.

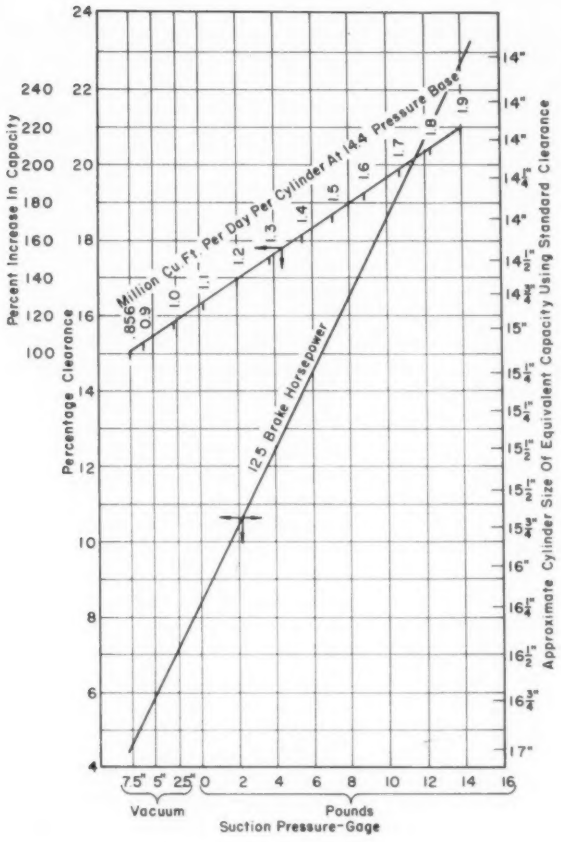

Percent Increase In Capacity
Percentage Clearance
Million Cu. Ft. Per Day Per Cylinder At 14.4 Pressure Base
125 Brake Horsepower
Approximate Cylinder Size Of Equivalent Capacity Using Standard Clearance
75" 5" 25"
Vacuum
Pounds
Suction Pressure-Gage

FIGURE 1—(left) This 17x20-inch compressor cylinder has been flexible enough to keep engines fully loaded by changing clearance. (Discharge pressure, 60 psig; barometric pressure, 14.4; normal clearance, 4.17 percent; maximum clearance, 23.3 percent)

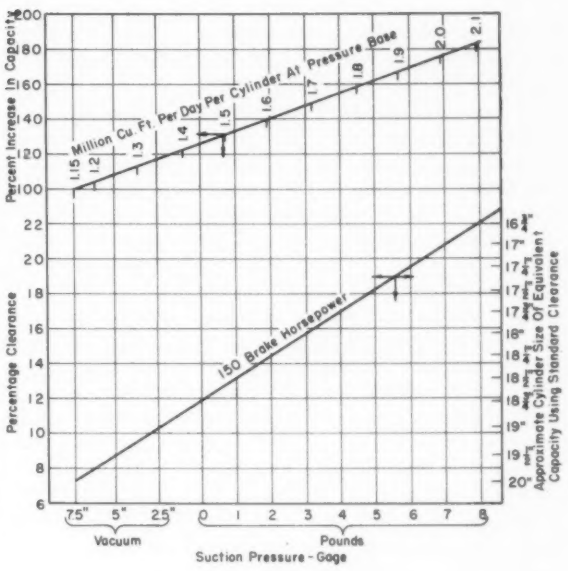

Percent Increase In Capacity
Percentage Clearance
Million Cu. Ft. Per Day Per Cylinder At Pressure Base
150 Brake Horsepower
Approximate Cylinder Size Of Equivalent Capacity Using Standard Clearance
75" 5" 25"
Vacuum
Pounds
Suction Pressure - Gage

FIGURE 2—(above) A 20x14 cylinder. With 60 psig discharge pressure, suction can be varied from 7.5 inches Hg vacuum to 8 psig with the engine load remaining constant at 150 bhp. (Barometric pressure, 14.4 psi; normal clearance, 7.22 percent; maximum clearance, 22.5 percent)

Flexible Compressors With Piston Pockets

Phillips has put clearance pockets in 1,000 pistons to handle changing suction pressures. Pockets can be opened or closed to keep engines fully loaded

J. E. Mallow
Phillips Petroleum Company
Bartlesville, Okla.

MORE THAN 1,000 clearance pocket pistons have been manufactured for use in Phillips' compressor operations. A large number are also being used by other compressor operators. All new and re-bored compressor cylinders for Phillips' operations are equipped with these pistons.

When added clearance is needed, it is available in the pistons without any additional cost. The cost of these pistons is only a small amount above a conventional piston. Since this type of piston has been available, practically all new compressor cylinders are purchased at least 10 percent larger than required for initial operations and clearance is added to the piston to give greater flexibility in future operations.

Flexibility Needed. In the design and operation of natural gasoline plants, flexibility of reciprocating compressors is important to handle maximum volumes of gas. This flexibility will prevent serious overloads on engines which can result in excessive maintenance costs.

In the design of new plants certain pressure conditions are anticipated, but new developments in the field may alter these conditions be-

fore the plant is placed in operation. Frequently, too, after the plant has been in operation a number of years, additional drilling or a change of proration schedules may increase or decrease available suction pressure at the plant. Flexibility of compressors is necessary to accommodate these changing conditions.

Old Solutions. In many of the earlier plants with the older compressors, a change in pressure conditions resulted in either a severe overload or underload on the power end of the compressor engine. A large number of the earlier compressor cylinders did not have any provision for adding clearance for a change in operating conditions. Most compressor manufacturers soon realized the need for flexibility in their compressors and made provisions for adding external clearance either in adjustable or fixed clearance bottles added to the head or through openings in the side of the cylinders.

The operator, however, still did not have the flexibility which might be required for changing compressor conditions. If the cylinder was equipped with an adjustable bottle, this gave flexibility up to the limit of the capacity of the bottle. The same held true on the fixed clearance bottles. Fabrication of additional bottles even in those days was expensive and with costs continuing to increase it is even more costly at the present time. There was also a limitation on the amount of clearance which could be effectively added in an external bottle. This was due to the fact that a large volume of gas compressed in the bottle could not always re-expand through the small opening in the head or the cylinder in time to be effective as clearance. In such instances, although the operator was of the opinion the compressors were properly clearanced for the operating conditions, the compressor was carrying an overload which could damage the power end.

During recent years practically all of the compressor installations have been of the right angle or "V" design. These engines are designed for maximum use of space, and in some instances where large compressor cylinders are required, there is insufficient space between cylinders to install external bottles of a large capacity. To overcome this handicap, large bottles have at times been installed above or below the cylinder and connected to the clearance openings by pipe nipples of the same size as the flange on the clearance opening in the cylinder. Again, it has been found that large volumes will not re-expand through the small pipe connection in time to be fully effective as clearance. In some instances, also, all the required clearance is added to the cylinder through the opening in the outer head. This, however, results in an unbalanced load condition on a double-acting cylinder and it is considered best to avoid this if possible.

First Plant Tried. A plant which Phillips installed in 1941 had grown until in 1945 it included 36-230 hp twin horizontal compressor units. Original design conditions were 0 psig suction and 55 psig discharge. New field developments had resulted in increased volumes with 8 psig suction pressure available at the plant. Since a majority of the compressor cylinders were of an older design, there was no provision for adding external clearance to take advantage of increased suction pressure and at the same time not over load the power end of the engine.

Consideration was given to the installation of smaller diameter compressor cylinders, but even at the time this would have resulted in an expenditure of approximately $100,000 in investment costs for new cylinders. Piping changes and labor for removal of the old and installation of new cylinders would have been in addition to the above price. Consideration also was given to the purchase of new cylinder heads equipped with clearance pocket openings. This, too, would have been costly along with the fact, as pointed out above, it would have resulted in unbalanced load conditions on the cylinders.

While trying to find a solution, the idea was conceived of using the clearance in the cored section of the piston casting. Patterns were fabricated for the manufacture of pistons with the cored section of the piston divided into eight pockets of equal size with four pockets on the head end and four on the crank end of the piston. The new clearance type pistons were manufactured and installed for a total cost of approximately $11,000. The compressors were then placed in service and pockets opened on each end of the piston for the maximum available suction pressure without imposing an overload on the power end of the engine.

In the intervening years, either due to proration or some fluctuation in field conditions, the suction pressure has varied; but it has been possible to keep the engines fully loaded through adjustment of clear-

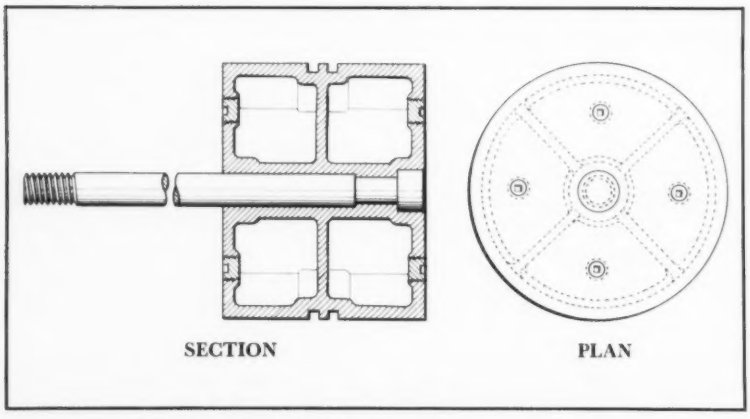


FIGURE 3—Typical piston shows arrangement of pockets.

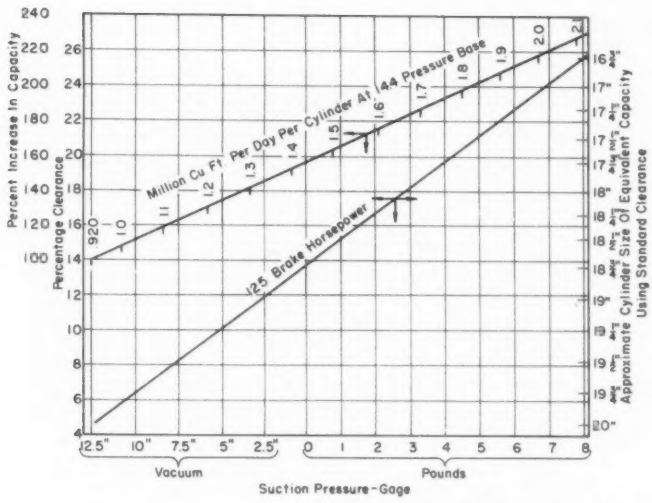

Percent Increase In Capacity
Percentage Clearance
Million Cu Ft Per Day Per Cylinder At 14.4 Pressure Base
125 Brake Horsepower
Approximate Cylinder Size Of Equivalent Capacity Using Standard Clearance
12.5" 10" 7.5" 5" 2.5" 0 1 2 3 4 5 6 7 8
Vacuum
Pounds
Suction Pressure-Gage

FIGURE 4—(above) A 20x20 compressor cylinder with clearance added. (Discharge pressure, 45 psig; barometric pressure, 14.4; normal clearance, 4.96 percent; maximum clearance, 25.39 percent)

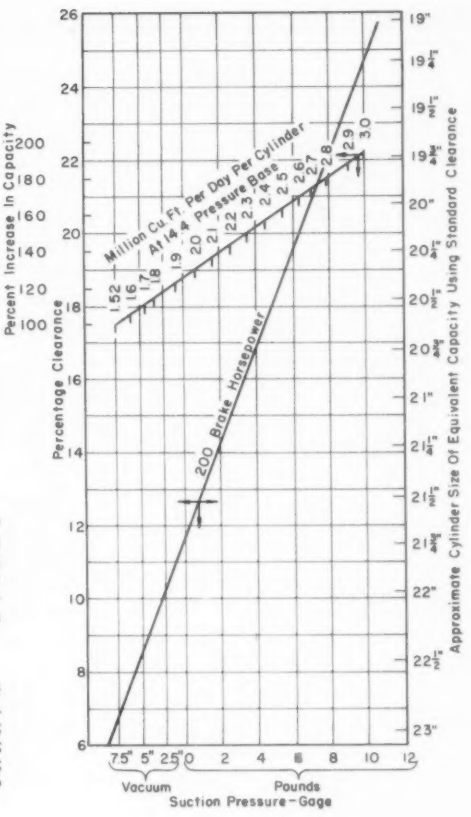

Percent Increase In Capacity
Percentage Clearance
Million Cu Ft Per Day Per Cylinder At 14.4 Pressure Base
200 Brake Horsepower
Approximate Cylinder Size Of Equivalent Capacity Using Standard Clearance
7.5" 5" 2.5" 0 2 4 6 8 10 12
Vacuum
Pounds
Suction Pressure-Gage

FIGURE 5—(right) A 23x14 cylinder with clearance added. (Discharge pressure, 60 psig; barometric pressure, 14.4; normal clearance, 6.4 percent; maximum clearance, 25.65 percent)

ance to the compressor cylinders by opening or closing pockets in the pistons.

Figure 1 shows the flexibility of a 17 by 20-inch compressor cylinder equipped with a clearance type piston and installed at the first plant. As a result of the success of these new pistons, Phillips immediately contacted compressor manufacturers requesting that they provide this type of piston in all new compressor cylinders purchased by Phillips with a bore diameter above 9 inches. The pistons 9 inches in diameter and smaller, of course, do not have sufficient area inside the cored section of the piston to justify a clearance pocket type piston design. Compressor manufacturers were very cooperative in complying with this request and were licensed to manufacture the pistons under the Phillips' patent.

Booster Station Tried. At the time this piston was developed, a booster station was in the planning stage which would require five 600-hp compressor engines. It was anticipated that initial suction pressures would be approximately 25 psig and ultimately this would decrease to around 0 psig. For the initial conditions a 14-inch diameter cylinder would be required and a 20-inch diameter for the ultimate. To keep the engines fully loaded, an intermediate size would be required before the ultimate conditions would be reached. There would also be costly piping changes for each cylinder change in addition to the high cost of these cylinders. There would likewise be periods in which the engines would be underloaded because there had not been sufficient

TABLE 1
VOLUMES AND EFFECT OF INTERNAL CHAMBERS IN COMPRESSOR PISTONS

Size (Inches)	No. of Pockets	Vol. of One Internal Pocket (Cu. Ins.)	Total Internal Cl. Added (Cu. Ins.)	PERCENT CLEARANCE		PERCENT VOLUMETRIC EFFICIENCY		Reduced Size of Cylinder Using Internal Clearance (Inches)
				Normal	Maximum	Normal*	Reduced*	
10 x 20	4	71.5	286.	7.04	16.5	82.9	64.25	9 x 20
10 x 20	8	51.4	411.2	6.1	19.5	84.7	58.25	8½ x 20
12 x 20	8	85.25	682.	4.6	19.95	87.9	57.30	10 x 20
14 x 20	8	140.	1120.	5.85	24.05	85.5	49.50	10½ x 20
16 x 20	8	185.	1480.	4.58	22.98	87.8	51.20	12¾ x 20
17 x 20	8	215.	1720.	4.17	23.3	88.7	50.70	14 x 20
18 x 20	8	245.	1960.	3.87	23.39	89.1	49.70	14 x 20
20 x 20	10	254.6	2546.	4.96	25.39	87.1	46.30	15 x 20
20 x 14	8	166.4	1331.2	7.22	22.45	82.5	52.40	16½ x 14
23 x 14	8	278.	2224.	6.4	25.65	84.1	45.80	18 x 14
26½ x 20	8	535.	4380.	4.27	23.97	88.6	49.50	20 x 20
27½ x 20	8	587.	4696.	4.0	23.77	89.1	50.00	22 x 20
12 x 16	4	81.5	326.	7.0	16.25	83.0	64.70	10 x 16
16 x 16	5	140.	700.	6.0	17.08	84.9	63.10	14 x 16
14 x 12	8	127.	1016.	10.0	37.4	76.8	22.00	7¾ x 12

* Assuming that the compression ratio is 4 and the ratio of specific heats is 1.26.

decline in suction pressure to justify the change in cylinders.

It was decided to install initially the 20-inch diameter cylinders which would be required for the ultimate conditions and equip these clearance pocket pistons. Initially, in addition to the clearance in the pistons, it was necessary to remove the suction valves from the crank end of several of the cylinders of each engine. This method of reducing the load on an engine however does not always prove too satisfactory. Indicator tests of unloaded ends of compressor cylinders have shown horsepower losses of as much as 15 bhp per cylinder, depending on the cylinder displacement and pressure involved. Because of this loss it is best to add clearance to the cylinder by a method whereby it will be effective and at the same time not be operating the cylinder in an unbalanced load condition. It should be pointed out though that in the above instance it would not have been possible to use the large diameter cylinders in the initial operation without the clearance provided by the clearance pocket pistons. In the intervening years the suction pressure has declined to 2 psig. During this time, however, it has been possible to keep the engines fully loaded by closing pockets in the pistons, thereby reducing the added clearance.

Investment charges for new cylinders have been avoided and by preventing excessive overloads on the power end of the engine, maintenance costs have been held to a minimum.

Figure 2 shows the flexibility that can be obtained in a 20 by 14-inch compressor cylinder of the same type as installed in the booster station. With 60 psig discharge pressure, the suction pressure can be varied from 7.5 hg vacuum to 8 psig with a load of 150 brake horsepower per cylinder on the engine remaining constant. The clearance added by the pockets in the piston has the effect of reducing the size of the compressor cylinder from 20 to 16½-inches in diameter with capacity increasing from 1.15 MMcfd to 2.1 MMcfd.

The amount of flexibility is dependent to a great extent on the length as well as the diameter of the compressor piston involved, but in general compares favorably with those shown in the figures.

Fears Dispelled. Figure 5 is a sketch of a typical clearance pocket type piston. Note that the pocket openings are closed by installation of a countersunk type pipe plug. Threads in the pocket openings are machined to specified tolerances and precision pipe plugs are used to insure a proper fit. Originally, some expressed a fear that the pipe plugs would work loose and damage the cylinder and piston. This however, has not been the experience. Those expressing this fear overlooked the fact that all standard cast iron pistons cored to reduce weight have pipe plugs to close up the openings in the cored section.

There was also the fear that the heat of compression of the gas in the piston pockets would cause excessive expansion of the piston, then seizure in the cylinder. All pistons, however, have been machined with standard running clearances and there has not been any experience of piston seizure as a result of piston expansion.

Initially there was some difficulty due to core sand or machine cuttings left in the pocket of the piston entering the cylinder when the pocket was opened. This, however, was corrected by setting up definite specifications for cleaning the pockets at the time the pistons were manufactured.

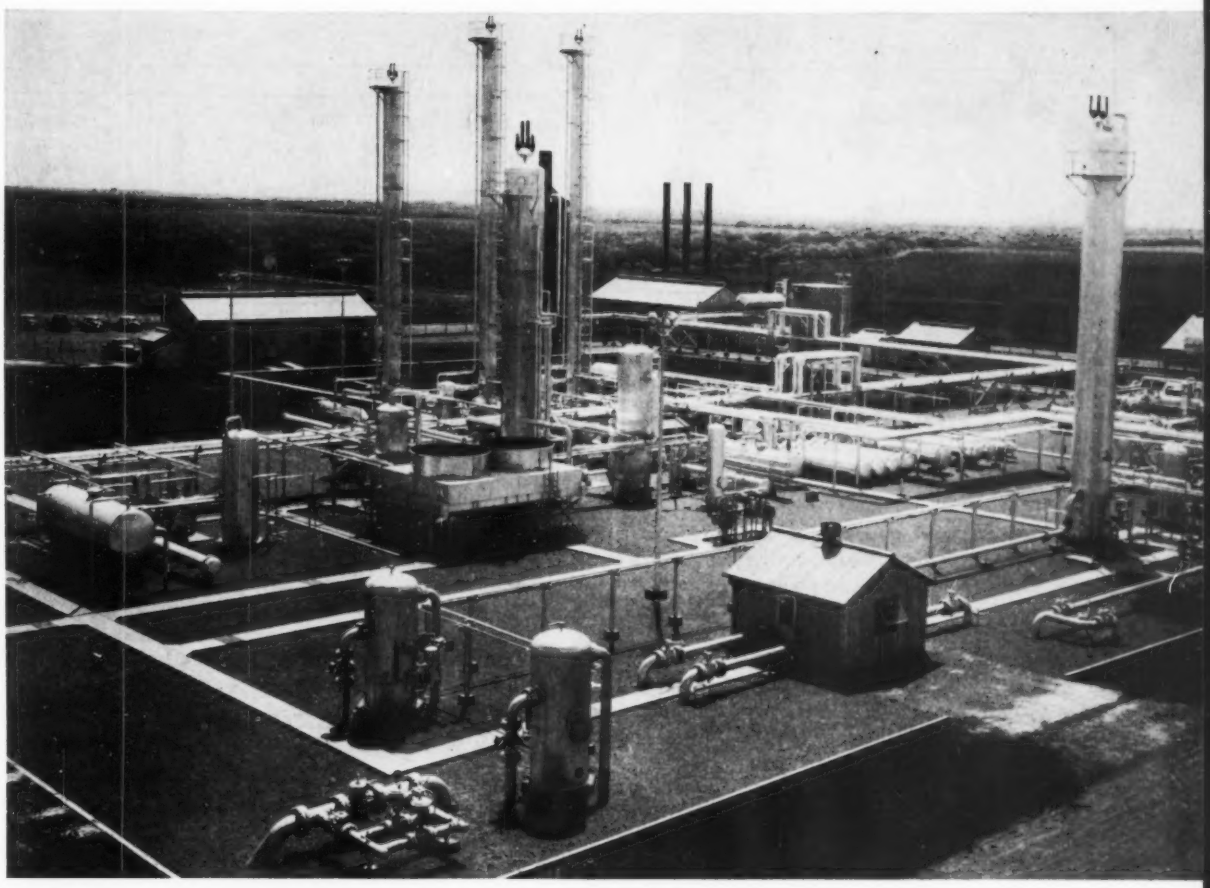
Advantages. With continual changes in proration schedules these pistons have proved exceptionally beneficial in keeping compressors operating at full efficiency with only a small labor cost involved in changing the celarance. The piston has also made it possible to salvage a number of compressor cylinders which otherwise would not have been suitable for use. If a project requires a certain size cylinder and that size is not available among the surplus, a larger size is often used. By use of the pocket type piston the size of the cylinder is, in effect, reduced to the actual size required.

The same thing can be accomplished by lining large diameter cylinders down to a small diameter, but this is considerably more costly than the purchase of a clearance pocket piston. Pressure rating of the cylinder, of course, must be considered in instances where a large diameter cylinder is used in place of the smaller cylinder.

Pistons are manufactured either from cast iron castings or, in the case of exceptionally large diameter when weight may be a factor, sometimes are fabricated from steel. Steel pistons are metalized with a bronze material on the wearing surface to prevent excessive wear in the cylinder. Pistons of both materials have been highly satisfactory. # #

About the Author

J. E. Mallow received his B.S. degree in 1932 from North Texas State College at Denton. In 1933 he joined Phillips Petroleum Co. in the Natural Gasoline department. Since that time he has served as operator of engines, plant engine foreman, machine shop inspector, district mechanical maintenance superintendent, and since 1953 as mechanical maintenance superintendent for the Natural Gasoline department.



PART 1–Plant Operation

Operator's Handbook For Gasoline Plants

Prepared by plant superintendents and operating staff, this handbook is written so that the new and experienced operator can understand the most important operations of a natural gasoline plant . . .

Manufacturing Department, Bay Petroleum Company, A Division of Tennessee Gas Transmission Company, Houston

FOUR OF THE MAJOR ITEMS of consideration in the design, erection, and operation of a modern gasoline plant are:

Feed Stock
Process Flow
Design Characteristics
Products

FEED STOCK

The composition of raw natural gas varies for each well and producing area, but usually methane is the predominant component, with smaller amounts of ethane, propane, butanes, pentanes and heavier hydrocarbons.

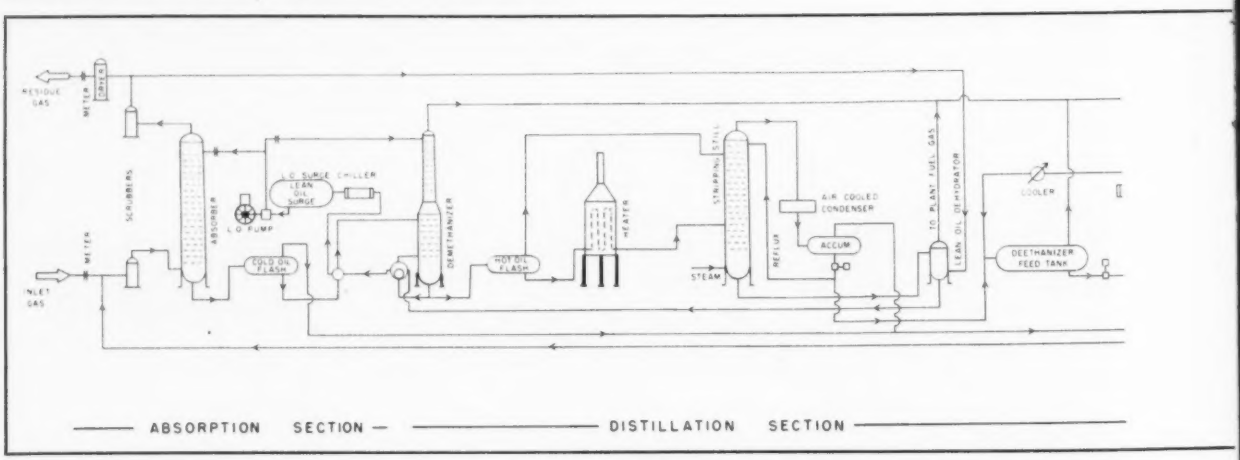


FIGURE 1—Flow scheme for a typical natural gasoline plant

In addition, the raw gas contains unwanted compounds such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), mercaptans (other sulfur compounds), water, and certain solid impurities such as dirt or other mineral compounds. Before entering the hydrocarbon extraction facilities of a gasoline plant, the unwanted compounds must be separated from the raw gas stream. This is partly accomplished by the equipment installed at the well site. A gas-oil separator is usually installed at each well for the purpose of removing some of the heavier hydrocarbons (crude oil or condensate) from the gas stream. Most of the free water and solid impurities such as dirt, drilling mud, and other mineral compounds are also removed in the gas-oil separator. Various types of separation equipment have been developed including adsorption and low temperature units. The quantity and quality of the raw gas stream will usually govern the type of separation equipment used at the well site. It follows, that the type of wellhead equipment installed will affect the composition of the feed stock to a gasoline plant.

The water which is not removed by the wellhead separator may still be a problem in the field gathering system, depending upon the pressure at which the system operates. At certain temperature and pressure conditions, water will react with hydrocarbons to form hydrates, which are crystalline substances resembling ice. These hydrates often plug the gathering lines, metering stations, and often process equipment in the gasoline plant if not controlled. Methods of hydrate control include the injection of inhibitors such as ammonia, methanol, other alcohols and glycols which combine with water and depress the hydrate point. Line heaters are often used to raise the flowing gas temperature above the hydrate point. Another method is the use of desiccants to adsorb the water from the gas stream. Still another method employs certain glycols to absorb the water. In any event, water is an undesirable which must be removed from the feed stock.

The other undesirable compounds previously mentioned—carbon dioxide and hydrogen sulfide—cause corrosion in the process equipment and can be removed by processes using solutions of ethanolamines. Conditioning natural gas streams to remove these unwanted compounds requires a large capital investment. Raw natural gases which contain less than 1.0 gallon of propane and heavier hydrocarbons per 1,000 cubic feet can sometimes be processed *economically* if they are free of these undesirables.

PROCESS FLOW

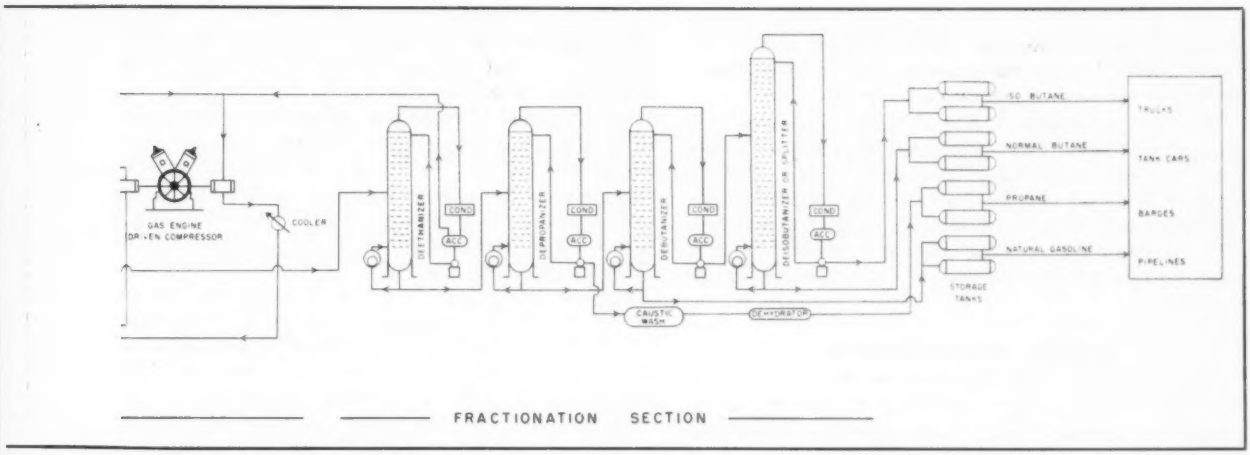
The feed gas volume and composition to a natural gasoline plant determines the type, size, and amount of processing equipment required for each plant. Basically, however, all plants are designed for the same process flow. The flow of the gas through a typical plant can be followed in Figure 1. Most plants will have an absorption unit which separates the ethane and heavier hydrocarbons from methane.

A brief process flow description is as follows:

Absorption Plant. First, the gas is measured and passed through an inlet gas scrubber. This clean gas stream then enters an absorption tower which separates the ethane and heavier hydrocarbons from the methane (by absorption into a lean oil stream). The lean gas stream from the absorber passes out of the plant through an outlet scrubber which removes any absorption oil entrained in the lean stream. The lean oil which has absorbed the heavier hydrocarbons is now called the rich oil stream.

Stripping. This rich oil stream now enters the rich oil flash tank where a pressure drop from the line pressure causes some of the methane and ethane to flash. This tank helps to reduce the load on the demethanizer. The methane and ethane from this flash can be used as fuel or may be further processed to remove the ethane as a product. The rich oil is fed into a demethanizer where more of the ethane and methane is removed as a top product.

The rich oil, which has been heated in the demethanizer, now flows into another flash tank. This hot oil flash removes more of the light hydrocarbons and reduces the load on the next piece of equipment—the oil heater. In the heater the temperature of the oil is raised to a pre-



shows absorption, distillation and fractionation sections.

determined level and then passed to the stripping still. The oil is stripped of its absorbed hydrocarbons in this still while the recovered hydrocarbons are condensed, cooled, and sent to the fractionation unit. The lean oil is cooled in several steps and recycled through the absorber.

There are many variations of this absorbing and stripping operation but they all accomplish essentially the same job—recovering the ethane and heavier hydrocarbons from the raw natural gas.

Fractionation. The recovered liquid hydrocarbons from the still are collected in a rundown tank. The vapors which flash in this tank are compressed and liquefied. The liquid is sent to the deethanizer feed tank along with the product from the still rundown tank. The stream is pumped into the deethanizer, which removes as an overhead product the ethane and lighter materials. The bottoms product from the deethanizer is fed into a depropanizer which removes the propane. Each of these towers or columns separates two components. The composition of the product depends upon the operating conditions and this, in turn, upon the specification of the desired product. The flow for each of the fractionating columns is similar to that of the deethanizer.

Many variations of the absorption type of gasoline plant are used to remove the liquid hydrocarbons from the raw natural gas. These hydrocarbons may be removed by absorption, compression, a combination of absorption and compression, or refrigeration.

Refrigeration Plant. The flow through this type of plant can be followed on Figure 2. Gas passes through a high pressure separator which removes the liquid.

The gas is then dehydrated to remove any remaining water vapor which could cause the formation of hy-

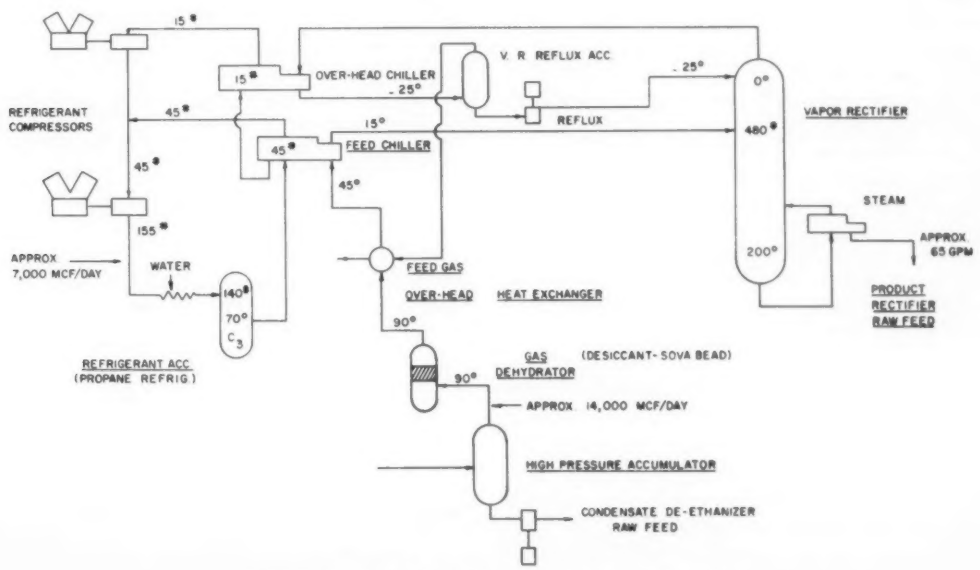


FIGURE 2—Flow scheme for typical refrigeration plant.

drates. These hydrates are readily formed at the low temperatures used in refrigeration plants and will plug or impair the flow of gas through the line.

The gas is cooled in several stages and then put through a rectifier. The top product from this rectifier is essentially methane, ethane, and some propane. The top product is cooled and the liquid which accumulates in the reflux tank is put back into the rectifier as a reflux. The gas from the reflux accumulator passes from the plant and the reboiler bottoms are fed into a fractionating unit.

DESIGN CHARACTERISTICS

The theory and design of equipment in a typical gasoline plant can be quite complicated because of varied operating conditions. Each plant must be designed and calculated on an individual basis because each one is just a little different from the next. Certain design characteristics will be discussed briefly in the following paragraphs, without going into actual calculations.

Basic Separation Methods. Three general methods of separation of raw natural gas are employed:

1. Absorption into a low-vapor-pressure liquid
2. Adsorption on activated clays or carbon
3. High-pressure, low-temperature fractionation

Combinations of these operations are also employed, particularly absorption and fractionation.

Absorption. Gas absorption is a unit operation in which a soluble component of a gas mixture is dissolved in a liquid. Absorption, in general, is the penetration of one substance into another. The purpose of absorption is to recover light hydrocarbons from a gas (methane) that were not removed in compression or other field separation processes.

The absorption reaction is quite interesting. It has often been compared to fractionation. However, in the case of fractionation, the liquid and the vapor are free to exchange places. As part of the vapor condenses on a tray there are corresponding evolutions of vapor from the liquid on the tray brought about by the exchange of the heat of vaporization. In absorption, the liquid and vapor do not vaporize or condense to any extent, and the lighter components are transferred from one phase to the other. That is, material exchange takes place primarily in one direction, from the gas phase to the liquid phase. Some individuals have visualized the absorption reaction as a tug of war between the absorption oil and methane over the ownership of the pentanes, butanes, etc.

A typical absorber consists of a steel tower filled with trays of bubble-caps or other devices to give a large area and intimate contact between the absorption oil and the raw natural gas. Many companies also use towers filled with rocks of a specified size or specially manufactured pieces of material known as Raschig Rings or Beryl Saddles. Preference for any one of these materials is usually based on the user's experience.

The problem of determining how much absorption oil should be used to obtain the correct operating conditions on an absorption unit can be very complex. The common method of expressing the amount of absorption oil used is gallons of oil per thousand standard cubic feet of gas (60° F., 14.7 psia). With these units the absorption factor can be determined. In determining the oil-to-gas ratio, it is necessary to decide how much of a certain low-boiling component (key component) can be allowed in the final gasoline.

The absorption factor and the oil circulation for this compound are then computed. The other components will also be absorbed to varying extents, depending upon their vapor pressures or equilibrium constants. The amount of absorption is inversely proportional to the vapor pressure. Thus the absorption factor is different for each component even though the oil circulation is the same for all. The optimum value of the absorption factor for any particular plant is primarily a function of the value of the product involved and the cost of recirculating oil. The absorption factor or oil recirculation increases rapidly as large percentages of a key component are absorbed. In most situations the economical amount of key component to absorb in gasoline plants is between 90 and 95 percent rather than the 99 percent value that is so frequently employed in the design. The cost of operation mounts rapidly as more than 90 percent of the key component is recovered. It may cost twice as much to recover 99 percent as to recover 90 percent of the key component.

The temperature of the absorbing oil is a very important factor. The cooler the lean oil is when it enters the absorber, the better its ability to pick up the hydrocarbons in the rich gas stream.

Stripping. Stripping removes the liquid hydrocarbons from the absorption oil and can be considered to be the reverse reaction of absorption. The same type of equipment is used with many of the design characteristics remaining the same. The stripping still in absorption units involves both fractionation and stripping. The top part of the still is a fractionator, and any part of the gasoline not removed in that section is removed in the lower part by steam stripping.

The simplest type of primary recovery absorption-stripping unit is shown in Figure 3. Many different innovations have been devised to make this operation more efficient, but the diagram shows the absolute minimum which is essential.

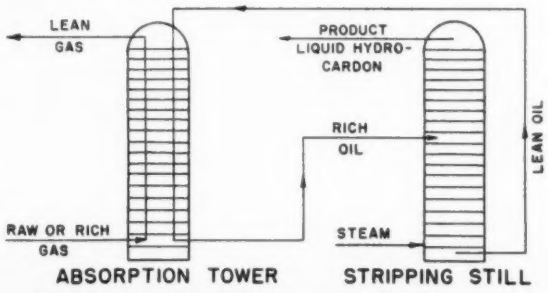


FIGURE 3—Simplest type of absorption-stripping unit.

Demethanization. A demethanizer tower is used in the plant to remove some of the load from the stripping equipment. Demethanization is accomplished by operating the top of the tower as an absorber (with refrigeration and intercoolers optional) for the removal of some of the methane and ethane which has been absorbed in the rich oil. The bottom of the tower is heated so that it acts as a fractionator for the elimination of any methane or ethane which is still retained in the rich oil.

Adsorption. Adsorption takes place in a tower filled with a desiccant such as activated alumina or charcoal. The gas flows into the bottom of the tower and the desiccant adsorbs the methane first. As heavier hydrocarbons come through in the gas, they bump the small methane molecules off their "seat." This process takes place continuously until the activated material is saturated with hydrocarbons. The tower will then be bypassed and heated or regenerated, with the hydrocarbons passing off overhead. The hydrocarbons are then condensed and ultimately fractionated into the desired components.

This is essentially the method which is used to determine the amount of gasoline present in a gas. This test is known as the charcoal test and has been adopted as a standard of the industry.

Refrigeration. Low temperature, high pressure fractionation is gaining in popularity because the equipment is becoming more efficient in design and operation. The charge gas is compressed and cooled until a part of it becomes a liquid. The liquid is then fractionated into the products which are needed.

The problem in this process is how to economically cool the charge gas so that the resulting liquid can be recovered and fractionated.

Fractionation. When the raw gasoline and lighter hydrocarbons have been separated from the rich oil in the stripping unit, they must be separated into individual groups of hydrocarbons having certain specified properties such as boiling range, vapor pressure, molecular weight, etc.

The fractionating tower consists essentially of three parts (Figure 4):

1. Heater or reboiler
2. Tower proper
3. Overhead condenser

The feed is heated (preheater) and admitted near the center of the tower on a feed tray. When the feed enters

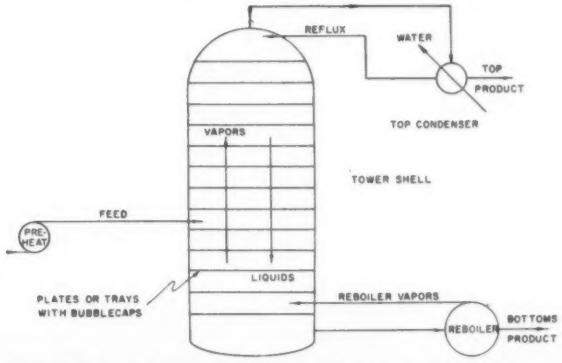


FIGURE 4—A fractionating tower includes a reboiler, tower proper and overhead condenser.

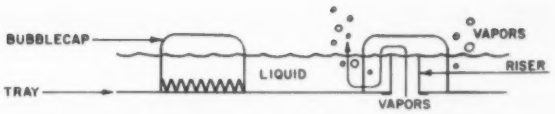


FIGURE 5—How vapor flows through the bubble caps.

the tower, some of it is vaporized and moves upward. The liquid which is left over moves downward. The vapors which are moving upward have to move through a bubble-cap (Figure 5), and in so doing come in contact with liquid on that plate. This contact causes the more active or lower boiling molecules to take on a load of heat from the less active and higher boiling molecules. If the molecule takes in enough heat, it will vaporize and continue moving up the tower. Some of these molecules (the lowest boiling group) will move all the way up the tower and out of it as the top product while the highest boiling molecules will work their way down the tower and will finally be removed as the bottom product. The more contacting surface between the liquid and vapor the better the separation that can be effected.

The vapors move through the riser, and can only get out of the cap by going through the slots in the skirt of the cap proper. These slots are covered by the liquid on the plate so that the vapors must move through the liquid and thus the vapor-liquid contact is established. There are many different methods for obtaining this contact but the bubble-cap is one of the better known methods.

The tray consists of these bubble-caps, weirs, and downcomers. The liquid moves down the tower through a downcomer (Figure 6), over a weir, across the plate or tray, over another weir and into another downcomer to the next or lower tray. The vapors move upward through the bubble-caps.

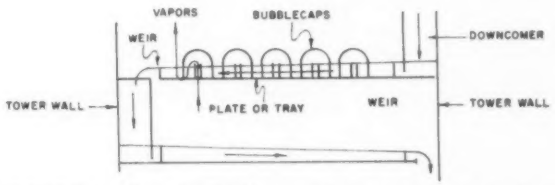


FIGURE 6—How the liquid moves from one tray to another.

The reboiler section of a fractionating column (Figure 4) heats the bottoms product, and injects the vapors back into the bottom tray of the tower. These reboiler vapors then start moving up the tower exchanging heat with lighter molecules. The purpose of the reboiler is to supply heat to the tower. This removes any light ends from the bottoms product and thus makes a more pure product.

The overhead condenser cools vapors from the top of the tower, condensing them either partially or totally. Some of this cooled product is pumped back into the tower onto the top tray and is known as reflux. The amount of reflux helps determine the quality of the overhead product.

The size of the tower is determined from the amount of feed stock. The number of plates in the tower depends on the degree of separation desired; and the efficiency of these plates depends upon the number of bubble-caps and the speed at which the feed stock is put through the

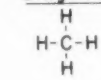
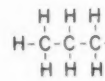
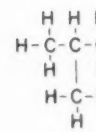
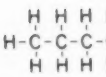
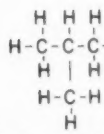
tower. The design of each tower depends on the degree of separation desired and the type of service that the tower is in.

Many other pieces of equipment are necessary in a plant operation but they just assist the three basic units of absorption, stripping, and fractionation in doing their jobs efficiently and economically.

PRODUCTS

All products recovered in natural gasoline plants have one thing in common—they all are made of carbon and hydrogen. Compounds containing these two elements only have been given the family name of hydrocarbon. Different members of the family are distinguished by the use of a name and chemical formula. Hydrogen is identified by an "H" and carbon by a "C". Methane, the hydrocarbon usually referred to as natural gas, is the first member of the family and is diagrammed as H or CH_4.

This indicates that methane is composed of one atom of carbon and four atoms of hydrogen. The hydrocarbons usually found in raw (unprocessed) natural gas can be shown as:

Name	Formula	Diagram
Methane	CH_4	
Ethane or C_2	C_2H_6	
Propane or C_3	C_3H_8	
Butane or n-C_4 (Normal)	C_4H_{10}	
Isobutane or i-C_4	C_4H_{10}	
Pentane or n-C_5	C_5H_{12}	
Isopentane or i-C_5	C_5H_{12}	

Hydrocarbon compounds are classified according to the number of carbon and hydrogen atoms they contain. Methane is the simplest hydrocarbon—all of the others are formed by adding a CH_2 group to the preceding compound. Each of these hydrocarbon compounds exhibit certain properties that are different from the properties of any other compound. These are known as physical properties and include:

Boiling point—the temperature in degrees Fahrenheit at which a liquid will change into a vapor or gas, usually taken at atmospheric pressure.

Freezing point—the temperature in degrees Fahrenheit at which a liquid will change into a solid, usually taken at atmospheric pressure.

Vapor pressure—the pressure which a measured amount of liquid will exert in a closed container at a specific temperature (usually 100 F.).

Specific gravity—the weight of a volume of material as compared to the weight of an equal volume of water, both measured under the same conditions (usually atmospheric pressure and a temperature of 60 F.).

Molecular weight—the combined weight of the individual atoms of a material; or the weight of one molecule expressed in grams and based upon the atomic weights of the elements.

For quality control purposes in a plant the vapor pressure, boiling point, and specific gravity of each product is usually taken at regular intervals. The resulting figures are compared to the same properties of the pure product and the amount of difference between these properties indicates the purity of the sampled product.

In the processing of natural gas the separation and purification of the products involves many different temperatures and pressures. Each hydrocarbon will have a different vapor pressure at the same temperature. Methane has the highest vapor pressure of any compound found in the plant. At ordinary temperatures it is impossible to keep methane as a liquid regardless of the pressure applied to it. Conversely hexane will remain a liquid at atmospheric temperature and pressure. The vapor pressure of any hydrocarbon found in a gasoline plant will increase with temperature.

An important classification of matter is by phase—solid, liquid and vapor. Each of these phases can be changed to the other by changing the temperature and/or the pressure on the substance. This is shown by the three phases of water—ice, water, and steam.

This review of composition and properties will help clarify why some of the process equipment is used in a plant and why the many different temperatures and pressures are necessary for its successful operation. Most of the equipment in a gasoline plant accomplishes its job by changing the temperature, pressure or concentration of a compound. These variables are the most important factors to control the operation of a plant.

In the final analysis, natural gas is processed to obtain materials needed to do certain jobs. Common uses of plant products include:

- Methane for home fuel
- Ethane for polyethylene plastic and anti-freeze
- Propane and butane for plastics, rubber and fuel
- Pentanes and heavier hydrocarbons for auto gasoline

TO BE CONTINUED

For acid gas removal . . .

Giammarco-Vetrocoke Processes

These new gas treating processes from Italy overcome some disadvantages of conventional processes and improve the economics for gas streams of high CO_2 content

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FOR ACID GAS removal, the new processes from Italy, Giammarco-Vetrocoke, show distinct advantages over conventional schemes. These processes have been applied in Europe for purification of coke oven and synthesis gases. Now, a plant is under construction in the United States for H_2S and CO_2 removal from high pressure natural gas. Interest in such processes has increased with the trend toward use of natural gas streams of very high CO_2 and H_2S content.

There are two distinct processes, one for the removal of CO_2 from gases essentially free of H_2S and another for selective H_2S removal. These processes are based on the absorption of acid gases in an alkaline solution containing inorganic or organic additives.

Here is a complete study of how these processes compare with conventional schemes, both technically and economically.

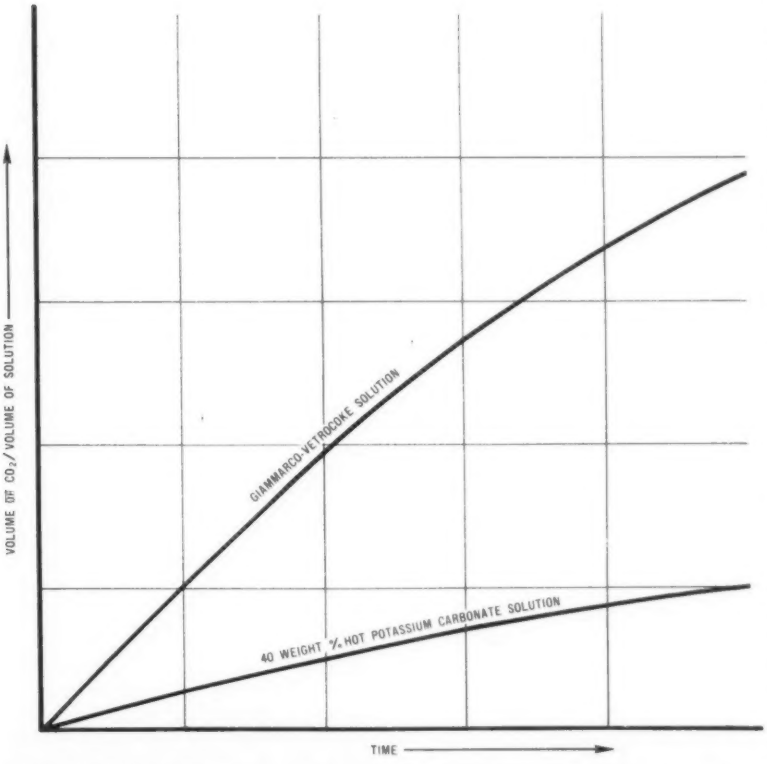

FIGURE 1—CO_2 absorption rate is much higher in Giammarco-Vetrocoke solution (containing arsenic trioxide) when compared to conventional hot potassium carbonate solution. Thus, shorter absorbers and strippers are needed.

How Process Developed. Ethanolamine solutions are most commonly used for acid gas removal from various industrial gas streams. However, this method has certain disadvantages, principally (1) large steam requirements for solution regeneration, (2) both hydrogen sulfide and carbon dioxide are absorbed simultaneously by the amines commondly used, mono-and diethanolamine, (3) the formation of stable compounds between the amines and gas impurities such as COS, CS_2 and HCN. The nonselectivity for H_2S and the formation of nonregenerable compounds are of importance in the treatment of nonhydrocarbon gases. Such gas streams, especially those derived from coal and sulfur-containing petroleum oils, contain appreciable quantities of COS, CS_2 and HCN.. The amine losses due to reaction with these compounds are of such magnitude that the use of the processes is uneconomical.

Selective H_2S absorption in the presence of CO_2 is desirable when a pure stream is required for further utilization, for example, the production of urea. Some selectivity for H_2S is obtained by use of tertiary amines such as triethanolamine and methyldiethanolamine. However, appreciable quantities of CO_2 are absorbed even by these amines, especially if complete H_2S removal is required.

The most widely used new carbon dioxide removal process, next to amines, utilize concentrated aqueous sodium or potassium carbonate solutions and are operated at relatively

high temperatures. Such solutions, especially those containing potassium carbonate, have a high capacity for carbon dioxide when it is present at relatively high partial pressure. As the absorption and desorption are carried out at essentially the same temperature the heat requirements for solution regeneration are appreciably lower than in the amine processes.

Sodium and potassium carbonate solutions have been used for many years for acid gas removal from a variety of gas streams. A process utilizing absorption of CO_2 in such solutions at high temperatures has been described and patented in Germany as far back as 1904[1]. More recently, a similar process using concentrated hot potassium carbonate solution (up to 40%) has been developed by Benson and Field of the U. S. Bureau of Mines.[2,3] These investigators have made a considerable contribution by developing design criteria permitting application of the process to many commercial carbon dioxide removal problems.

One distinct disadvantage of processes using alkali carbonate solution is the fact that the rate of absorption and desorption of carbon dioxide is relatively low. It is generally believed that the low rate of absorption of CO_2 is due to a slow chemical reaction occuring in the solution between dissolved molecular carbon dioxide and hydroxyl ions. Based on the assumption of this mechanism, attempts have been made to discover catalysts or activators which would increase the rate of this chemical reaction. Two French investigators, Riou and Cartier,[4,5] studied a number of activators including glycerol, dextrose, sucrose, various low boiling alcohols, ethylene glycol and formaldehyde; and found that addition of some of these materials in relatively small quantities to the carbonate solution produces a marked increase in the rate of carbon dioxide absorption. However, no commercial processes have been developed as a result of these studies.

Intensive studies of a large number of possible solution activators were conducted by Giammarco of the Italian firm of Vetrocoke-Azotati who discovered a number of very effective organic and inorganic activators. A commercial process known as the Giammarco-Vetrocoke process[6] was developed and applied first at the Vetrocoke installations at Porto Marghera, Italy and later in several large plants in Europe.

Concomitantly with the CO_2 removal process a novel H_2S removal process[7] was developed in which either the same or similar solutions are used as in the CO_2 removal process. By proper selection of the solution composition it is possible to remove H_2S and CO_2 simultaneously in a single operation; or the two acid gases may be absorbed separately in two consecutive steps. The latter scheme is particularly advantageous if a pure stream of CO_2 is required for urea synthesis or dry ice manufacture.

Both the CO_2 and H_2S removal processes have been applied commercially in a considerable number of installations in Europe and have been recently made available in the United States through Fluor and other engineering and construction companies. Gases treated by the processes in European installations are primarily coke oven and synthesis gases; however, extensive pilot plant runs have also been conducted with hydrocarbon gases. At present a plant is under construction in the United States using the Giammarco-Vetrocoke processes for H_2S and CO_2 removal from high pressure natural gas.

The processes are applicable to the treatment of practically any industrial gas stream. Examples are natural gases; product gases from partial oxidation units; shift converter outlet gases; coke oven gases; etc. The processes are particularly suitable for the treatment of gases containing CO_2 at substantial partial pressures. Another outstanding application is the removal of H_2S from gas streams containing impurities which form heat stable compounds with certain amines.

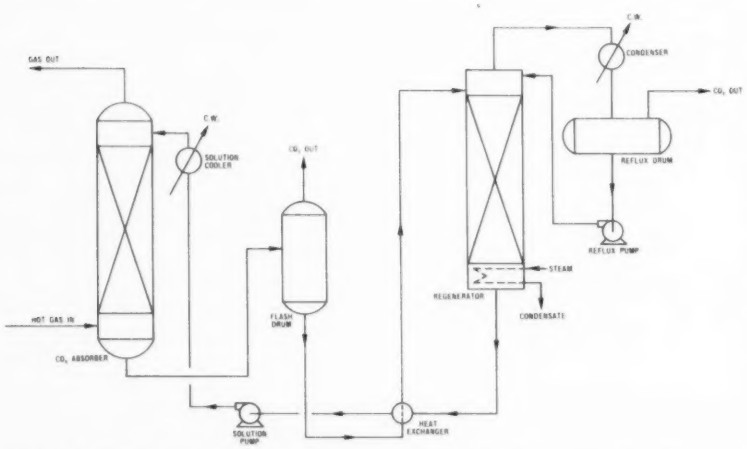

FIGURE 2—Flow scheme for Giammarco-Vetrocoke CO_2 removal with steam regeneration.

GIAMMARCO-VETROCOKE CARBON DIOXIDE REMOVAL PROCESS

This process utilizes hot aqueous alkali carbonate solutions which are activated by either small amounts of organic substances, or by substantial amounts of inorganic substances. The concentration of active absorbent material in the solution is comparable to that of a hot potassium carbonate solution used in a well-designed plant. The inorganic additives include such compounds as arsenic trioxide, selenous and tellurous acid. In most commercial installations the arsenic trioxide activator is used. The presence of substantial amounts of arsenic trioxide in the absorbing solutions results in a very marked increase in the rate of absorption and desorption of carbon dioxide. This phenomenon is shown graphically in Figure 1, which presents a comparison between the

rate of absorption of carbon dioxide at 1 atmosphere partial pressure and room temperature in a 40 per cent potassium carbonate solution and a typical solution used in the Giammarco-Vetrocoke process.

Because of the much higher rate of CO_2 absorption and desorption obtained in the Giammarco-Vetrocoke process than in a conventional hot potassium carbonate process, somewhat shorter absorbers and strippers are required. Since the activated solution is also regenerated more readily than a conventional hot potassium carbonate solution, regeneration can be effected with considerably reduced steam consumption. Regeneration is also possible by use of air as stripping vapor, which further reduces the steam requirements. Regeneration under pressure is also possible, permitting recovery of carbon dioxide under pressure which is important where the carbon dioxide is used in other processes.

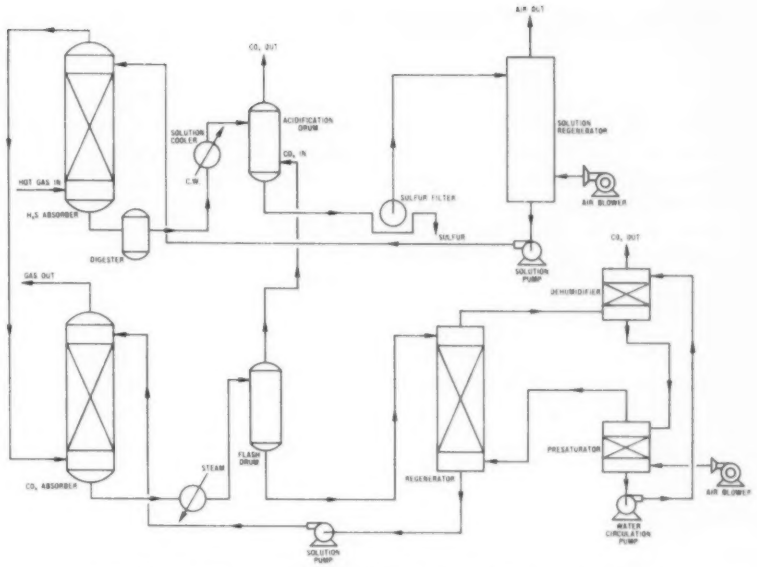

FIGURE 3—Giammarco-Vetrocoke H_2S and CO_2 removal process.

Process Description. A typical flow diagram of a carbon dioxide removal plant is shown in Figure 2. In this case, which is typical for the treatment of a gas stream containing only CO_2, the solution is regenerated with steam. The CO_2 containing gas enters at the bottom of the absorber which may be any contacting device insuring intimate countercurrent contact between the gas and the liquid, and the purified gas leaves the absorber at the top. The lean solution enters the absorber at the top and flows from the bottom of the absorber to the flash drum where the pressure is reduced and an appreciable portion of the carbon dioxide is released. The partially stripped solution flows from the bottom of the flash drum through a heat exchanger, where it is heated by exchange with the regenerated solution, to the top of the regenerator where the remaining CO_2 is stripped from the solution. Heat is supplied to the bottom of the regenerator by means of indirect steam. The lean solution leaves the bottom of the stripper and after heat exchange with the incoming rich solution is returned to the top of the absorber.

The process scheme including air regeneration is shown in Figure 3, which is a typical flow diagram for the treatment of a gas stream containing both hydrogen sulfide and carbon dioxide. The gas is first passed through an absorber where the hydrogen sulfide is removed, and then enters the absorber of the CO_2 removal section. The H_2S removal process is discussed in detail in a later portion of this article. The flow scheme of the CO_2 removal section is very similar to that described above. Lean solution enters at the top of the absorber and CO_2 is removed in a countercurrent operation. The rich solution leaving the bottom of the absorber is heated before it enters the flash drum from where the partially stripped solution flows to the top of the regenerator. Final stripping is obtained by contact with a stream of preheated and water saturated air which enters at the bottom of the regenerator. The mixture of CO_2 and air leaving the top of the regenerator is washed with a stream of cold water in the dehumidifier in order to recover heat and condense water contained in the gas stream. The cooled mixture of air and CO_2 leaving the top of the dehumidifier is vented to the atmosphere. The water stream leaving the bottom of the dehumidifier is used to presaturate and preheat the incoming air in the presaturator. This arrangement results in a maximum of heat recovery and a minimum of water loss.

TABLE 1—Comparison of CO_2 Removal Processes—Typical Operating Data

PROCESS	Giammarco-Vetrocoke Steam Stripping	Giammarco-Vetrocoke Air Stripping	Hot Potassium Carbonate Steam Stripping	MEA 20%
SYNTHESIS GAS				
Pressure, PSIG:	350	350	350	350
Inlet Gas Temp., F:	280	280	280	100
CO_2 In, Vol. %:	34.3	34.3	34.3	34.3
CO_2 Out, Vol. %:	0.2	0.5	2.0	10-25 PPM
Relative Solution Capacity:	1.0	0.7	0.6	0.7
Relative Steam Consumption:	1.0	0.3	1.7	3.0
NATURAL GAS				
Pressure, PSIG:	1000	1000	1000	1000
Inlet Gas Temp., F:	100	100	100	100
CO_2 In, Vol. %:	28.0	28.0	28.0	28.0
CO_2 Out, Vol. %:	0.1	0.5	2.0	10-25 PPM
Relative Solution Capacity:	1.0	0.7	0.75	0.65
Relative Steam Consumption:	1.0	0.25	1.9	3.0

Comparison With Other Processes. The advantages of the Giammarco-Vetrocoke process can be seen from the comparison shown in Table 1. Two types of gases, a typical ammonia synthesis gas and a natural gas, both containing high concentra-

tions of carbon dioxide were considered. The Giammarco-Vetrocoke process with air regeneration and with steam regeneration is compared with the hot potassium carbonate process and the ethanolamine process using a 20 per cent MEA solution. The values shown for the CO_2 content of the outlet gas in the case of the steam regenerated Giammarco-Vetrocoke process are quite conservative. Presently available operating data indicate that CO_2 concentrations of 0.05 vol. per cent are obtainable in a properly designed installation. The most outstanding feature of the process is the very appreciable saving in steam consumption as compared to both the hot potassium carbonate and the aqueous MEA system.

The effluent gas from both the hot potassium carbonate plant and the Giammarco-Vetrocoke plant in the synthesis gas case has to be further treated to obtain a final CO_2 concentration of 10-25 ppm required for ammonia synthesis. However, the plant necessary for final clean-up is considerably smaller for the Giammarco-Vetrocoke process than for the hot potassium carbonate process. CO_2 concentrations of 0.5 vol. percent are acceptable in treated natural gas for domestic consumption and no further treatment is therefore necessary for such gas streams when the Giammarco-Vetrocoke process is used. Furthermore, because of the extremely low solubility of oxygen in the solution, air stripping can be used and full advantage can be taken of the heat economy provided by the Giammarco-Vetrocoke system.

An important advantage of the Giammarco-Vetrocoke process is the non-corrosive nature of the treating solution. It appears that trivalent arsenic is a very powerful corrosion inhibitor under the operating conditions encountered in such plants. The existing commercial installations are constructed entirely of carbon steel and during several years of operation not a single case of corrosive equipment failure has been observed.

Impurities present in the gas such as oxygen, carbonyl sulfide, carbon disulfide, mercaptans, and hydrogen cyanide, have no significantly adverse effect on the solution. Small amounts of undesirable side reaction products can be removed from the solution by means of a very simple procedure.

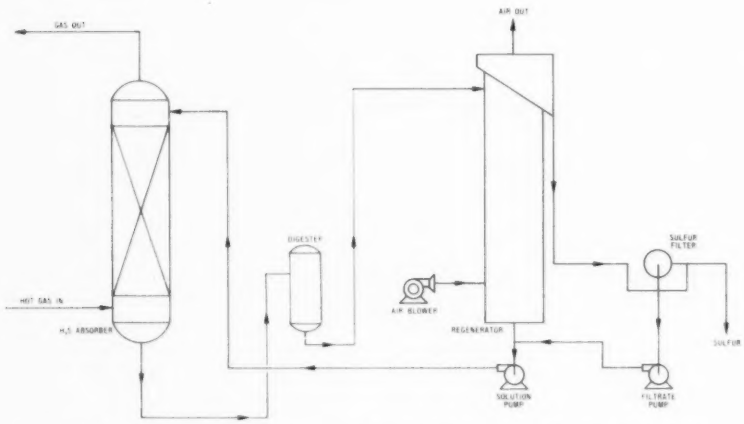

FIGURE 4—Giammarco-Vetrocoke H_2S removal process with air regeneration.

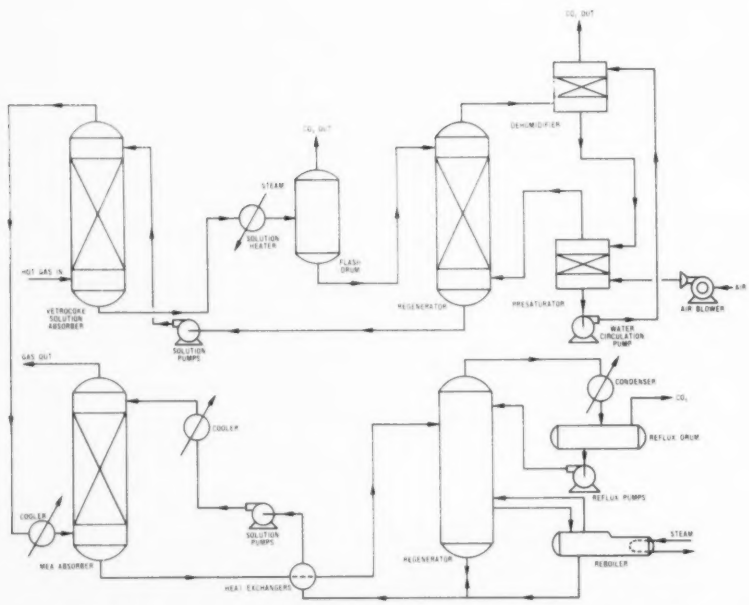

FIGURE 5—Giammarco-Vetrocoke and aqueous monoethanolamine, Case I.

GIAMMARCO-VETROCOKE H_2S REMOVAL PROCESS

This process is based on the absorption of hydrogen sulfide in solutions containing a mixture of alkaline arsenites and arsenates. Considerable flexibility such as selective H_2S absorption or simultaneous absorption of both H_2S and CO_2 can be obtained by proper selection of the proportion of arsenite to arsenate and pH of the solution. The chemistry of the process is quite complex; however, the over-all reaction mechanism of the absorption-regeneration cycle can be represented by several steps, occurring either simultaneously or consecutively.

Hydrogen sulfide is first absorbed

by reaction with arsenite and the resulting compound is subsequently converted to monothioarsenate by reaction with arsenate. Because of the combination of arsenite and arsenate rapid and complete H_2S absorption is obtained. The extremely low vapor pressure of H_2S over monothioarsenate insures minimum H_2S content in the treated gas—less than 1 ppm—even when the process is operated at high temperatures and low pressures.

The combination of monothioarsenate and arsenite and the operating conditions employed permit the application of the process to the treatment of gases of very high CO_2 content. In addition, side reactions are minimized and only negligible amounts of thiosulfate accumulate in the solution over long periods of operation.

In the next step monothioarsenate is decomposed to elemental sulfur and arsenite by lowering pH of the solution. This may be achieved by several different methods depending on the solution composition and the operating conditions. The preferred method for solutions of relatively high pH consists of contacting the solution with CO_2 under pressure. In this operation the carbonate contained in the solution is completely converted to bicarbonate, resulting in lowering of pH and separation of elemental sulfur. Carbonate is never completely converted in the absorption step, even if gases of very high CO_2 content are treated, and consequently elemental sulfur is not precipitated.

In the final step trivalent arsenic formed is reoxidized to the pentavalent form by air or oxygen and the solution is recycled to the absorber. In another version of the process—when solutions of relatively low pH are used—acidification is effected simultaneously with the oxidation of trivalent to pentavalent arsenic. Since arsenic acid is an appreciably stronger acid than arsenious acid oxidation results in lowering of solution pH and precipitation of sulfur.

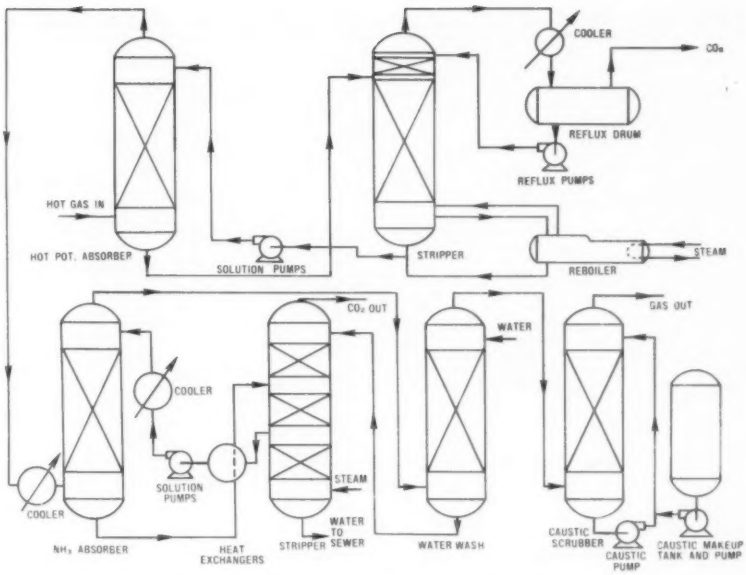

FIGURE 6—Hot potassium carbonate and aqueous monoethanolamine, Case II.

Elemental sulfur may be removed from the system either by filtration, or as is done in several industrial installations, by flotation in the oxidizing vessel. The elemental sulfur is normally washed with water which yields a relatively pure product containing only a few tenths of 1 percent of arsenic. Pure sulfur may be obtained by recrystallization in conventional equipment.

Process Description. The flow scheme of the process is shown diagrammatically in Figures 3 and 4. The scheme shown in Figure 3 includes acidification with carbon dioxide under pressure, while this step is omitted in the version presented in Figure 4. Turning to Figure 3, it is seen that the hydrogen sulfide containing gas is fed to the bottom of the absorber, which, again, may be any efficient liquid gas contacting device, where it is contacted countercurrently with the lean solution entering at the top of the vessel. The rich solution is withdrawn at the bottom of the absorber and flows to a surge vessel called the digester, where the relatively slow conversion reaction of thioarsenite to monothioarsenate is completed. The solution then flows to the acidification vessel where it is treated with a stream of CO_2. In the scheme shown in Figure 3, the CO_2 is taken from the flash drum of the CO_2 removal section which follows the H_2S removal plant. The slurry containing elemental sulfur is withdrawn from the acidifier, the sulfur is removed by filtration and the solution is fed to the top of the oxidizer where trivalent arsenic is reoxidized to pentavalent arsenic by contact with air.

The flow scheme shown in Figure 4 is very similar to that shown in Figure 3 except that the acidification vessel is omitted. The solution leaving the digester is fed directly to the top of the oxidizer where the trivalent arsenic is converted to pentavalent arsenic and at the same time elemental sulfur is liberated and removed from the solution by flotation.

TABLE 2—Comparison of H_2S Removal Processes—Typical Operating Data

PROCESS	Giammarco-Vetrocoke	Thylox	Ferrox	Manchester	Tri-Potassium Phosphate	MEA 20%	DEA 20%
Pressure, PSIG:	ATM.	ATM.	ATM.	ATM.	400	65	65
Inlet Gas Temp., F:	100-300	100	100	100	100	100	100
H_2S In, Gr./100 SCF	300-500	300-500	300-500	500-1000	450	2000	2000
H_2S Out, Gr./100 SCF	<0.1*	10**	5	0.25***	5-10	1-5	10-20
Solution Capacity Grains/Gal.:	600	40	70	10	470	2100****	1200****

* One stage absorption.
** One stage absorption; 0.25 Gr./100 SCF claimed for two stage absorption process.
*** Six stage absorption with fresh solution to each stage.
**** This figure applies when the inlet gas contains only H_2S and decreases proportionally with increasing CO_2: H_2S in inlet gas.

Comparison With Other Processes. Certain typical operating

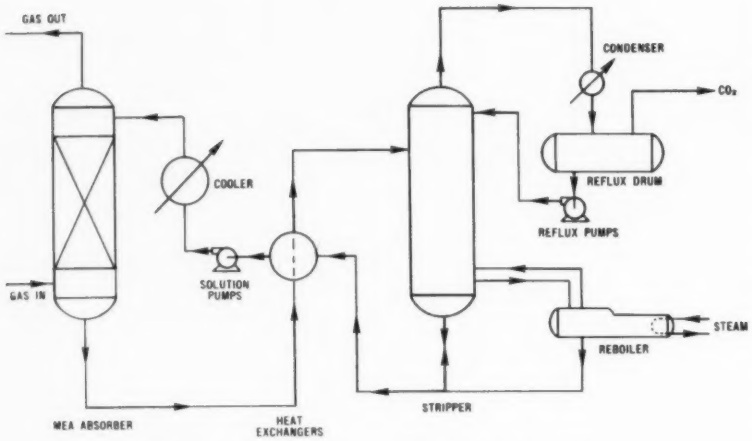

FIGURE 7—Aqueous monoethanolamine, Case III.

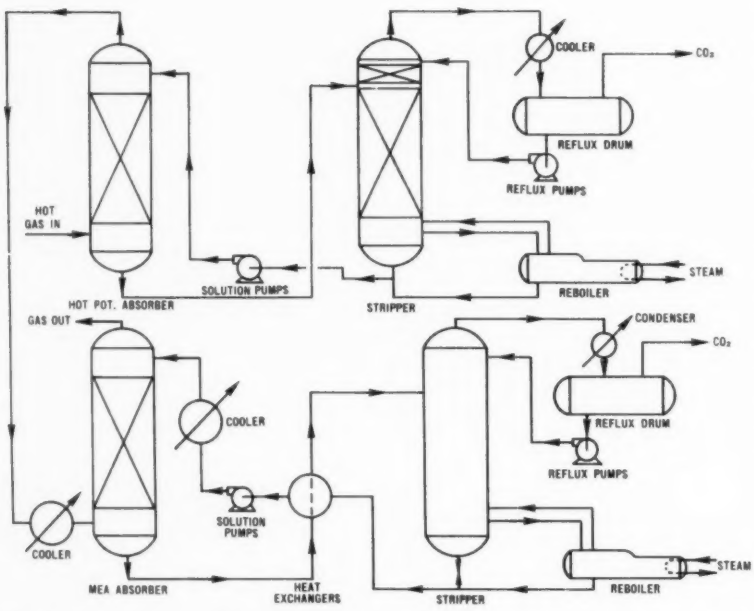

FIGURE 8—Hot potassium carbonate, aqueous ammonia and caustic scrubbing, Case IV.

characteristics of the Giammarco-Vetrocoke H_2S removal process are compared with those of other commercially used H_2S removal processes in Table 2. The comparison includes three liquid oxidation-type processes, viz., the Thylox, the Ferrox, and the Manchester processes, and three processes based on H_2S absorption by acid-base reaction. The oxidative processes are selective for H_2S in the presence of CO_2, while of the other processes only the tripotassium phosphate process is somewhat selective. In the amine processes using both MEA and DEA, essentially all the CO_2 contained in the gas has to be absorbed in order to obtain maximum removal of H_2S. Ethanolamine processes using methyldiethanolamine and triethanolamine are somewhat selective; however, because of the unavailability of extensive commercial operating data, these processes have been omitted from this comparison. The oxidative processes are normally used for the treatment of coal gases at essentially atmospheric pressure. In order to obtain a meaningful comparison relatively low pressure applications of the amine and tripotassium phosphate processes were selected.

The advantages of the Giammarco-Vetrocoke process are quite apparent. All other H_2S removal processes operate typically at absorption temperatures of about 100 F. This is necessary because of the high vapor pressure of hydrogen sulfide over these solutions which determines the purity obtainable in the treated gas. The Giammarco-Vetrocoke process is operable at temperatures ranging from 70 F. to 300 F., primarily because of the extremely low vapor pressure of hydrogen sulfide over the solution, and also, because of the very rapid rate of H_2S absorption. In commercial installations hydrogen sulfide content in the treated gas of less than 1 ppm have been obtained at operating temperatures on the order of 250 F.

The solution used in the Giammarco-Vetrocoke process has an appreciably higher capacity for hydrogen sulfide than solutions used in the Thylox, Ferrox, Manchester and tripotassium phosphate processes. The value given in Table 2 is conservative, and considerably higher capacities have been obtained. The two amine solutions show appreciably higher solution capacities than the Giammarco-Vetrocoke solution; however, it should be kept in mind that MEA and DEA absorb both H_2S and CO_2, and that, therefore, the capacity of the solution for H_2S decreases in direct proportion with increasing ratio of CO_2 to H_2S in the inlet gas.

In cases where both hydrogen sulfide and carbon dioxide are present in the gas, the two-step treatment shown in Figure 3 will yield an extremely pure stream of carbon dioxide because of the complete removal of hydrogen sulfide in the first treating operation.

Most oxidative processes are plagued by the presence of considerable amounts of undesirable side reaction products in the circulating

TABLE 3—Process Schemes Compared in Economic Study—Synthesis Gas

Case No.	Process Scheme	Figure No.
I	Giammarco-Vetrocoke (Air Regeneration) 20% Aqueous MEA	5
II	Hot Potassium Carbonate-20% Aqueous MEA	6
III	20% Aqueous MEA	7
IV	Hot Potassium Carbonate-Aqueous Ammonia-Sodium Hydroxide	8
V	Water-20% Aqueous MEA	9

TABLE 4—Process Schemes Compared in Economic Study—Natural Gas

I	Giammarco-Vetrocoke (Air Regeneration)	3
II	Giammarco-Vetrocoke (Steam Regeneration)	2, 4
III	Hot Potassium Carbonate	...
IV	20% Aqueous MEA	7

TABLE 5—Basis for Estimating Operating Cost

DIRECT COSTS	
Steam @	$0.55/1000 lbs.
Electricity @	$0.01/kw-h
Cooling Water @	$0.02/1000 gals.
Process Water @	$0.10/1000 gals.
Gas Losses @	$0.50/1000 standard cu. ft. for synthesis gas; $0.20/1000 standard cu. ft. for natural gas
Chemical Losses @	Current prices
Operating Labor	Foreman, $3.50 per hour; operators, $2.75 per hour; plus 22% burden to cover vacation, insurance and other benefits.
Maintenance	Annually 4% of plant investment, typically 60% for labor and 40% material.
Plant General	Annually 40% of total direct labor cost, includes nonoperating services and personnel up to and including plant manager.
On Stream Time	360 days for all cases.
INDIRECT COSTS	
Depreciation	Annually 10% of plant cost.
Taxes and Insurance	Annually 2.5% of plant cost.
Cost of Profit (Includes income tax, interest on investment and reasonable profit to owner to justify project)	Annually 25% of plant cost.

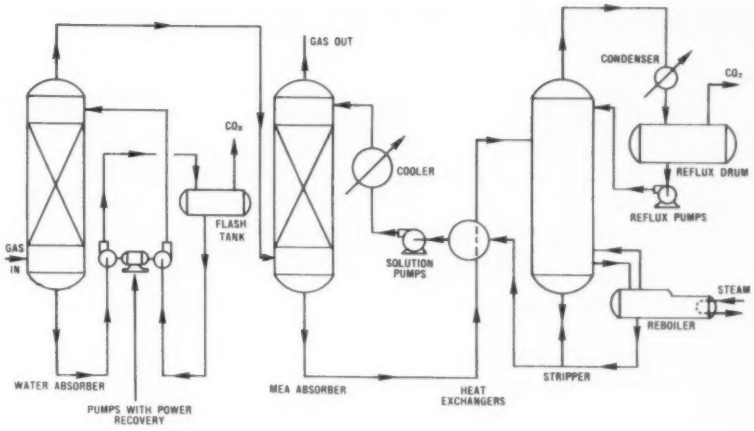

FIGURE 9—Water and aqueous monoethanolamine, Case V.

solution. This is especially true for the Ferrox and Thylox processes where a sizable portion of the sulfur is converted to thiosulfate from which the sulfur is not reclaimed in elemental form during solution regeneration. In the Giammarco-Vetrocoke process this side reaction is largely prevented and only an insignificant build-up of thiosulfate takes place over long periods of operation. Hydrogen cyanide, which is present in most coal and synthesis gases is absorbed by the solution and eventually converted to thiocyanate by reaction with elemental sulfur. Years of commercial experience have shown that this compound, which is the main cause of corrosion difficulties in most processes used to remove hydrogen sulfide from coal gases does not accumulate in the solution and, therefore is not a problem in the Giammarco-Vetrocoke process. A final but very important advantage of the process is the absence of corrosion in any portion of the system. During several years of commercial operation no corrosive failure of carbon steel equipment has been found.

PROCESS ECONOMICS

The economics of the Giammarco-Vetrocoke process have been compared with those of several other process schemes for removing high concentrations of carbon dioxide from gases. The following two gas streams were considered in these studies:

1. Twelve MMcfd of a typical ammonia synthesis gas containing 34 vol. percent of carbon dioxide at a pressure of 350 psig. The treated gas contained 10-20 ppm of carbon dioxide which is required for ammonia synthesis. The process schemes compared are shown in Table 3. This study is an extension of previous work done by J. F. Mullowney.[8]
2. Ninety MMcfd of natural gas containing 28 vol. percent of carbon dioxide and 2 grains/100 scf of H_2S at a pressure of 1,000 psig and 100 F. The carbon dioxide content of the treated gas ranged from 10-20 ppm to 2.0 vol. percent, depending on the process used (Table 1). The H_2S content was in all cases less than 0.25 grains/100 scf and

TABLE 6—Economics of Synthesis Gas Treating

CASE	I	II	III	IV	V
PROCESS USED	Giammarco-Vetrocoke-MEA	Hot Potassium Carb.-MEA	MEA	Hot Potassium Carb.-NH_4OH-NAOH	Water-MEA
Plant Investment	$372,000	$545,000	$607,000	$619,000	$778,000
Direct Operating Costs					
Utilities, $/Year					
Steam @ $0.55/1000 Lbs.	23,000	93,000	262,000	96,000	10,000
Electricity @ $0.01/KWH	25,000	19,000	19,000	21,000	41,000
Cooling Water @ $0.02/1000 Gal.	4,000	18,000	32,000	19,000	7,000
Process Water @ $0.10/1000 Gal.	...	...	...	1,000	...
Gas Losses @ $0.50/1000 SCF	6,000	7,000	4,000	5,000	37,000
Chemical Losses @ Cost	7,000	11,000	2,000	26,000	2,000
Sub Total	65,000	148,000	319,000	168,000	97,000
Operating Labor	47,000	47,000	47,000	66,000	47,000
Maintenance @ 4% Plant Cost	15,000	22,000	24,000	25,000	31,000
Plant General	18,000	20,000	21,000	27,000	22,000
Sub Total	80,000	89,000	92,000	118,000	100,000
Total Direct Costs	145,000	237,000	411,000	286,000	197,000
Indirect Operating Costs, $/Year					
Depreciation @ 10% Plant Cost	37,000	55,000	61,000	62,000	78,000
Taxes and Insurance	9,000	14,000	15,000	15,000	19,000
Total Indirect Costs	46,000	69,000	76,000	77,000	97,000
Total Operating Costs	191,000	306,000	487,000	363,000	294,000
Cost of Profit (Before Income Tax) @ 25% of Plant Cost	93,000	136,000	152,000	155,000	195,000
Grand Total Treating Cost $/Year	284,000	442,000	639,000	518,000	489,000
Treating Cost-Dollars per Thousand SCF Gas Treated	$0.07	$0.11	$0.15	$0.12	$0.12

meets pipe line specifications. The process schemes evaluated are shown in Table 4.

To obtain realistic investment costs for a typical plant, comparative process calculations were made for each case and all major equipment such as absorbers, strippers, heat exchangers, accumulators, knockout drums, pumps, storage facilities, etc., were actually sized. An experience factor was applied to the total equipment costs to obtain the approximate installed cost. All equipment was sized using the same basic information. For example, the same temperature approach was used for exchangers in all cases. Wherever necessary special alloys were provided for especially corrosive conditions.

Operating costs were estimated on the basis of utility and labor costs as shown in Table 5. The utility costs include pay-off of the capital investment as well as the normal operating costs of the facilities required to provide these services.

TABLE 7—Economics of Natural Gas Treating

CASE	I	II	III	IV
PROCESS USED	Giammarco-Vetrocoke W/Air	Giammarco-Vetrocoke W/Steam	Hot Potassium Carb.	Aqueous MEA
Plant Investment	$1,980,000	$1,570,000	$2,520,000	$2,900,000
Direct Operating Costs				
Utilities, $/Year				
Steam @ $0.55/1000 Lbs.	116,000	513,000	1,050,000	1,480,000
Electricity @ $0.01/KWH	147,000	102,000	176,000	182,000
Cooling Water @ $0.02/1000 Gal.	2,000	47,000	105,000	151,000
Process Water @ $0.10/1000 Gal.	4,000	1,000	7,000	1,000
Gas Losses @ $0.20/10000 SCF	50,000	33,000	70,000	30,000
Chemical Losses @ Cost	7,000	7,000	7,000	12,000
Sub Total	326,000	703,000	1,415,000	1,856,000
Operating Labor	126,000	126,000	126,000	98,000
Maintenance @ 4% Plant Cost	79,000	63,000	101,000	115,000
Plant General	61,000	55,000	63,000	58,000
Sub Total	266,000	244,000	290,000	271,000
Total Direct Costs	592,000	947,000	1,705,000	2,127,000
Indirect Operating Costs, $/Year				
Depreciation @ 10% Plant Cost	198,000	157,000	252,000	290,000
Taxes and Insurance	50,000	39,000	63,000	72,000
Total Indirect Costs	248,000	196,000	315,000	362,000
Total Operating Costs	840,000	1,143,000	2,020,000	2,489,000
Cost of Profit (Before Income Tax) @ 25% of Plant Cost	495,000	392,000	630,000	720,000
Grand Total Treating Cost $/Year	1,335,000	1,535,000	2,650,000	3,209,000
Treating Cost-Dollars per Thousand SCF Gas Treated	$0.041	$0.048	$0.082	$0.101

The results from the economic study are shown in Tables 6 and 7 for the synthesis gas and natural gas cases, respectively. The various flow schemes are presented in Figures 2 to 9.

The capital investment and operating costs for the synthesis gas Case 1, which is a combination of the Giammarco-Vetrocoke process with air stripping and an aqueous MEA plant for final purification, are considerably lower than those for all other cases. The main advantages of this scheme are the much lower steam requirements and the lower carbon dioxide content of the effluent from the Giammarco-Vetrocoke plant. This results in a very small MEA plant to obtain the specified purity. Also the Giammarco-Vetrocoke plant is constructed entirely of carbon steel while alloys are necessary in some portions of treating plants using other processes.

The Giammarco-Vetrocoke process both with air and steam regeneration show also appreciably lower capital investments and operating costs for the natural gas case, as can be seen in Table 7. In this application where no final clean-up of carbon dioxide is necessary, the advantage of the Giammarco-Vetrocoke plant is almost entirely in the operating cost because of the very low utility requirements. A small part of the difference in the operating costs between MEA and the other cases is due to treating the gas down to 10-20 ppm carbon dioxide which is lower than usually necessary to meet pipe line specifications. This, of course, is necessary to remove the hydrogen sulfide down to 0.25 grain/100 scf.

To take full advantage of the flexibility and many variations possible with the Giammarco-Vetrocoke processes, a careful economic analysis of each individual project is necessary. This is particularly true for cases involving H_2S removal where such factors as gas impurities and treating temperature have to be considered. In such cases the Giammarco-Vetrocoke processes offer advantages which can not be obtained with other known treating methods.

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Setting up Preventive Maintenance

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To develop a maintenance program that is truly preventive means using various indicators of wear and establishing limits of wear and component life. Actually, a great deal of this type maintenance exists, but has never really been integrated into an over-all program. For example, oil filter elements are usually changed either on an hourly life, or what might be a better basis, pressure drop across the filter. Pressure drop across heat exchangers is frequently used to determine fouling of units. A more accurate method might be by making a heat balance and a study of production losses. Whichever way is used, however, it's still an indicator to determine maintenance periods.

Considerable strides have been been made in the use of oil analyses to study engine oil and determine wear conditions and expectations. Newer techniques use spectroscopic analyses to determine metal build-up in the oil as a wear indicator.

Fuel consumption in some cases is an indicator of furnace troubles, along with Orsat analyses of exhaust gases. These two together can stop the use of inefficient burner equipment, as well as show up leaking settings. This last is becoming more important to plant operators as more and more direct fired heaters are in use and as the value of fuel climbs.

Design First. Where does preventive maintenance actually begin? In new plants, it starts with design. This is definitely one of the headaches, since we often get involved between two pictures—that of eventual economies and that of immediate investment economies—the latter always important in consideration of project payout. These economies can be reconciled, though frequently management must make the final decision.

One such decision which must be faced is the use of stand-by equipment. Usually this problem can be satisfied with a production loss and economic study, however, it is impossible and impractical to build any plant with 100 percent stand-by. Other methods of stand-by are those using equipment that will stand-by more than one service, or putting in two or three units for full load, so that the plant can operate at 50 percent to 60 percent capacity in some phases. If stand-by equipment is installed, then the preventive maintenance job is much easier.

Cooling equipment can often be designed so that advantage can be taken of cool weather, and equipment taken off the line for maintenance work. Fans, motors and gear drives can be installed in multiple units, so that they can be shut-off and inspected, as needed.

Plant design for maintenance must also take into consideration material specifications for various services. Actually, the prevention of wear and corrosion can be alleviated considerably by correct material usage. Again, the designer gets involved with economics and service life. In considering materials, we must not overlook the use of plastics, resins, and ceramics, which are rapidly becoming the maintenance crews' allies as much as alloy metals.

A further step in plant design is to consider the equipment itself, and be sure that its design will facilitate maintenance. Two common examples of this are to design heat exchangers so that water is on the tube side, which makes for easy cleaning of the scale, or if the water must be on the shell side due to economics, use square pitch tube layout to simplify cleaning. Finned tubes should be avoided where water is on the finned side and the heat levels are high. Scaling finned tubes is almost impossible mechanically, and usually chemical cleaning must be resorted to.

Finally, equipment location is important, and this is especially true where package equipment is being considered. Piping need not be obstructive to maintenance, if carefully planned. There have been installations where a cylinder head could not be removed because a line was directly in front of it.

Service Life. Now that you have a plant designed, you are in a direct line to the next headache. What methods should be used to develop service life and other data needed for a preventive maintenance program. Several methods and combination of methods might be offered:

1. Run a performance test of each piece of equipment in the new

plant (this is usually done anyway to check performance guarantees). These tests, then, become a base for any future operational test.

2. Establish test procedures which can quickly detect and anticipate operational troubles and need of care.
3. Review daily operating reports and note changes in operating conditions, such as increases in pressure drop or variations in temperature approach to anticipate heat exchanger trouble.
4. Review daily maintenance reports and determine trouble spots by frequency of failures.
5. Plot and use compressor engine capactiy curves, and watch decline of compressor volumes as equipment wear takes place.
6. Establish inspection procedures and equipment standards to anticipate wear spots. This is especially necessary for boiler and heater equipment where external inpection of tubes can forestall a rupture.
7. Review other plant experiences and service life as a guide to what may be expected.
8. Finally, set up a record system to evaluate your maintenance program and to guide your maintenance crews.

Selling Management. Now, the next headache is a big one. If it has been decided to really go after a preventive program, it must be discussed with management. Selling the program is in itself a big job. It is not easy to sell the idea of tearing something down unless actual repairs are needed, but a glance at the possible savings points to its advantages. The things you gain which can be sold to management are:

1. Continuous operation increases.
2. Reduction of emergencies.
3. Reduction of expensive labor items by reducing overtime costs.
4. Control of parts inventory.
5. Reduction of production losses.
6. Better satisfied personnel.
7. More effective use of men and equipment.

A further headache after doing a selling job to management is that of selling plant maintenance personnel. As a group, they generally are harder to sell, because they certainly have enough to do without tearing up equipment that is obviously running O.K.

There is a somewhat more specific cure for this besides talk and figures. Establish a maintenance program on some troublesome equipment and actually prove that breakdown can be avoided by preventive methods.

Basic Plan. There are two big headaches still to overcome. The first of these is to establish a basic plan for each plant, covering each piece

Gilsonite Cycling Plant
Location

1957

Preventive Maintenance Schedule

Code No.	Description Of Equipment	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct.	Nov.	Dec.
AC-1	Starting Air Compressor	1	4	2	1	1	2	1	1	1	1	4	1
AC-2	Starting Air Compressor	1	4	4	1	2	1	1	2	1	2	1	1
AC-3	Instrument Air Compressor	1	2	1	1	2	1	1	2	1	1	2	1
AB-1	Regeneration Air Blower	2	1	1	1	1	2	1	1	1	1	1	1
DC-1	Distillate Cooler	2	1	2	1	2	1	2	1	2	1	2	1
WC-1	Injection Water Cooler	2	1	2	1	2	1	2	1	2	1	2	1
B-1	Oil Field Boiler	4	4	4	1	1	1	1	1	4	1	4	4
CT-1	Cooling Tower	1	1	1	1	1	1	1	1	1	1	1	1

FIGURE 1—Records should be simple like this schedule on equipment.

of mechanical equipment, and the final headache is to determine what type of records shall be kept and who shall keep them. No one really asks for the job of keeping records, but in a preventive program, it must be done and it cannot be slighted if it is to be of value. No one, of course, wants to suggest increasing labor forces by adding a maintenance clerk, though in some centralized operations this is done. So some supervisor is going to get the duty and responsibility. This, then, calls for simple records.

To plan a maintenance program calls for some specified requirements, and these requirements, simplified, are as follows:

1. Entire program must be simple with a minimum of record-keeping.
2. Program must be reasonably and easily policed.
3. Program and records should tie in with other records required by main office.
4. Responsibility for records must fall on operating and maintenance personnel.
5. Program needs flexibility to take care of emergency needs and to correct repeating failures.

These requirements lead to specific aims, and these aims are as follows:

1. Emergency breakdown and repairs must be reduced to a minimum.
2. Manpower must be used more efficiently.
3. Supervisors responsible for continuous operation must be able to review easily the program at any stage.
4. Maintenance must be well-planned ahead of time, so that required parts, tools and personnel can be available.
5. Safety devices receive a periodic check and are tested, so that they can be relied upon to operate when needed.
6. Scheduled checks must be made on all equipment as programmed, so that minor troubles can be caught and not breed major failures.
7. Efficient use of fuel gas, steam, lubricating oil, electricity, parts and supplies reduces waste and, in turn, helps to reduce inventory by eliminating major recurring repairs.

The basic plan for the equipment, based on service time, must be a joint effort in each plant between engineering personnel, plant supervisors, and maintenance group to arrive at an agreed to service life and degree of maintenance to be performed. Service time is only a part of a preventive program; periodic inspection and use of indicators to spot trouble and develop service life are required to properly effect preventive maintenance. It is here that past records and experiences should be of great assistance.

The records themselves should be simplified as much as possible and, for ease of posting, use a numerical code system to indicate degree of maintenance. A basic code system could be as follows:

Code 1. Lubrication and Inspection.

Code 2. Inspection of oil condition, alignment, rod wear, etc., not requiring complete disassembly.

Code 3. Check of operability of safety devices.

Code 4. Complete overhaul.

These codes would then be listed on a schedule for each piece of plant equipment (Figure 1).

This schedule is prepared in duplicate, with the plant supervisor retaining the original and the maintenance group the duplicate for their records. It then is the responsibility of the plant supervisor to police the program and see that both records are posted.

Any maintenance program should be open to constructive criticism, study, and change. The principal long-range objective is to train personnel in the philisophy that their main responsibility is to keep all equipment operating at maximum efficiency. It is toward this end that, as each program progresses, better use of indicators will be found to arrive at economic service life and bring about a cure from periodic maintenance to true preventive maintenance.

This material was condensed from original presentation before the Natural Gasoline Association of America, Dallas, April 22-24, 1959. ##

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NGAA Committee on Water Pollution?

"Experience has taught us that cooperation with local State, and Federal officials is vital in seeing that a realistic approach is made to such problems as waste water disposal and water pollution. We have little to gain by attempting to hide from regulatory agencies. If we do, we are leaving ourselves open to the passage of laws and the adoption of rules under which we cannot operate.

"It might be suggested that a committee or other appropriate group be set up to further explore the relationship of the natural gasoline industry to the water conservation and pollution programs and to keep abreast of activities in this field. The committee might be active in working with governmental groups in determining the extent of the pollution and prescribing methods for its correction. Industry must be a part of any team prescribing standards under which the industry must live."

Condensed from the presentation by W. T. Ballard, "Waste Water Disposal."

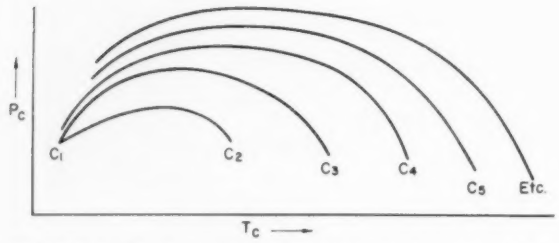

FIGURE 1—Hadden method uses this basic chart, the critical locus curves for methane binary hydrocarbon systems.

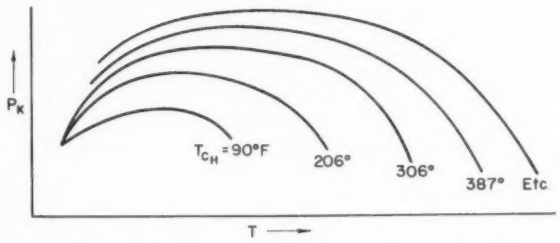

FIGURE 2—The same surface as seen in Figure 1 with the variables relabeled.

NGAA Computer Forum

Computing Convergence Pressure

Here's a way to check assumed P_k in flash calculations using the Hadden method and a computer

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DIGITAL COMPUTERS may be programed to select the proper convergence pressure, P_k, in the course of a flash calculation or other vapor-liquid equilibrium determination using the Hadden method. The NGAA K-Committee points out the advisability of checking P_k, a refinement in procedure, whenever P/P_k exceeds 0.4. Block diagrams and equations for programing the computer are offered to permit automatic checking of the assumed P_k when desired.

Background. Four years ago, United Gas Research Laboratory, through its participation on the K-committee, was among those who urged NGAA to sponsor curve fitting of the K-charts, recommended specific methods for doing so[1] and pointed out the many benefits to process engineering such a project would have.

It's too early to say that significant improvements and benefits to engineers will have resulted from the curve fitting project. However, practicing engineers may need additional help as to how best to use the "K-coefficients."

The method here describes how the computer, in addition to computing K's from a given set of coefficients, may also determine if the proper set of coefficients has been selected; that is, if K's for the appropriate convergence pressure, P_k, have been chosen.

Hadden Method for Defining P_k. A description of the Hadden method[2] has been summarized in text accompanying the NGAA K-charts. Figure 1 illustrates the basic working chart used, consisting of the familiar critical locus curves for methane binary hydrocarbon systems. A surface is generated by this family of critical loci. Hadden has

Table 1—Numerical Values of Equation Coefficients* Relating P_k, T and T_{c_H}

$$\log_{10} P_K = (A_0 + A_1 T_{c_H} + A_2 T_{c_H}^2 + A_3 T_{c_H}^3 + (B_0 + B_1 T_{c_H} + B_2 T_{c_H}^2 + B_3 T_{c_H}^3) T + (C_0 + C_1 T_{c_H} + C_2 T_{c_H}^2 + C_3 T_{c_H}^3) T^2 + (E_0 + E_1 T_{c_H} + E_2 T_{c_H}^2 + E_3 T_{c_H}^3) \frac{1}{T}$$

Units: T, °F; T_{c_H}, °F; P_k, psi

A_0 =	5117970640 (= 1.7970640)	C_0 =	—4652867215
A_1 =	4821987547	C_1 =	4412446502
A_2 =	4516185399	C_2 =	—4053578971
A_3 =	—4211887970	C_3 =	—3727626487
B_0 =	4893317175	E_0 =	5238234458
B_1 =	4539836405	E_1 =	—4950398134
B_2 =	—4355610874	E_2 =	—4618534164
B_3 =	4045029573	E_3 =	4332528255

* All coefficients reported in floating decimal arithmetic with exponent on the left and decimal point to the **left** of the mantissa.

used this surface to define P_k. Figure 2 shows the same surface with the variables relabeled. The ordinate is now P_k, the convergence pressure. The abscissa is now T, the equilibrium temperature and the parameter is Tc_H, the critical temperature of the hypothetical heavy component in the equilibrium liquid phase.

Mathematically, P_k is defined in terms of two independent variables

$$P_k = f(T, Tc_H) \qquad (1)$$

Tc_H is defined as follows:

$$Tc_H = \frac{\sum_{i=C_7^+}^{i=C_2} x_i M_i Tc_i}{\sum_{i=C_7^+}^{i=C_2} x_i M_i} \qquad (2)$$

where

x_i = mole fraction of component i in the equilibrium liquid phase,
M_i = molecular weight of component i,
Tc_i = critical temperature of component i.

TABLE 2—Comparison of P_k Computed from Equation (3) with Values Read from NGAA Critical Locus Plot

Tc_H	T	Eqn P_K	Chart P_K
92°F	60°F	944	880
	70	858	830
	80	800	780
	90	756	720
205	60	1402	1460
	80	1297	1410
	100	1262	1360
	120	1225	1290
	140	1160	1170
	160	1056	1050
	180	926	880
	200	774	680
276	60	1740	1690
	90	1657	1660
	120	1668	1610
	150	1619	1530
	180	1472	1400
	210	1237	1170
	240	954	880
	270	673	590
392	60	2413	2400
	100	2389	2450
	140	2490	2400
	180	2465	2280
	220	2254	2090
	260	1883	1790
	300	1429	1420
	340	984	1000
	380	613	600
456	60	2888	2790
	120	2915	2880
	180	3006	2825
	240	2756	2630
	300	2186	2230
	360	1486	1570
	420	862	820
646	60	5325	5300
	120	4967	5300
	180	4862	5150
	240	4683	4850
	300	4382	4500
	360	3965	3970
	420	3464	3400
856	60	14295	14700
	100	13592	13600
	140	12862	12600
	180	11981	11700
	220	10951	10900
	260	9810	10000
	300	8609	9250

Verifying Choice of P_k. The selection of an assumed P_k may be verified with the aid of the surface in Figure 2 or its equivalent mathematical form, Equation (1).

Step 1: After selecting a set of K's for an assumed P_k, a flash calculation is performed which yields an equilibrium liquid mole fraction analysis, x_i.

Step 2: This composition in turn is used to compute a value of Tc_H [Equation (2)]. P_k is then read off of Figure 2 at T and Tc_H or computed from Equation (1).

Step 3: If the computed P_k agrees with the assumed P_k, verification is achieved; otherwise an iterative method is suggested for improving the assumed value of P_k. The method of substitution yields satisfactory convergence so that an improved value for assumed P_k may be obtained by substituting the calculated P_k.

Automatic Verification of P_k by a Computer. Primary requirement for programing the above procedure on a digital computer is that a suitable "surface fit" for Figure 2 be obtained. This has been achieved through ordinary curve fitting procedures aided, of course, by a computer). The resulting equation for P_k found suitable is:

$$\log P_k = A + BT + CT^2 + E/T \qquad (3)$$

where

$$A = A_0 + A_1 Tc_H + A_2 T^2 c_H + A_3 T^3 c_H$$
$$B = B_0 + B_1 Tc_H + B_2 T^2 c_H + B_3 T^3 c_H$$
$$C = C_0 + C_1 Tc_H + C_2 T^2 c_H + C_3 T^3 c_H$$
$$E = E_0 + E_1 Tc_H + E_2 T^2 c_H + E_3 T^3 c_H$$

Numerical values for these sixteen coefficients are given in Table 1. The equation is valid over the temperature range, T, from 60 to 400 F. and over a critical temperature range, Tc_H, from 100 to 850 F. Data points used to obtain this fit were taken from the methane binary systems read from the critical locus plot on page 172 of the NGSMA (1957) handbook. A measure of the accuracy of fit is obtained from the comparison of Equation P_k versus Chart P_k found in Table 2.

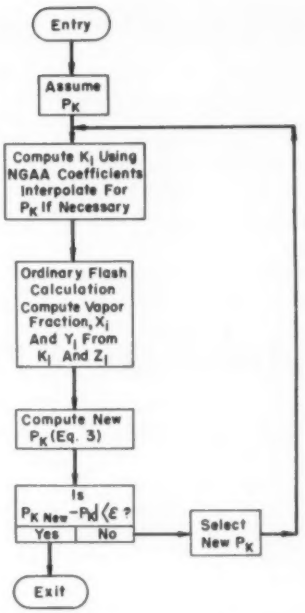
Entry
Assume P_K
Compute K_i Using NGAA Coefficients Interpolate For P_K If Necessary
Ordinary Flash Calculation Compute Vapor Fraction, X_i And Y_i From K_i And Z_i
Compute New P_K (Eq. 3)
Is $P_{K\,New} - P_K < \varepsilon$?
Yes
No
Select New P_K
Exit

FIGURE 3—Logical block diagram for a flash calculation subroutine which determines P_k based on an assumed P_k.

Application. Figure 3 suggests the logic in a block diagram for an overall flash calculation subroutine which would utilize Equation 3.

Original presentation was before the NGAA, Dallas, April 22-24, 1959.

LITERATURE CITED

[1] Goodwill, M. J. and Organick, E. I., "Use of K-Value Charts in Equation Form," Unpublished United Gas research report distributed to K-Committee in 1955.

[2] Hadden, S. T., *Chem Eng. Progress Symposium Series Vol. 49, No. 7*, 53 (1953).

K's From Chromatography Data

A RELATIONSHIP is indicated between K constants and the retention volumes measured in gas chromatography. The retention volume is the partition coefficient, β, for the component in the stationary phase. From definitions of the partition coefficients and the equilibrium constant, K, it is shown that these two are inversely related:

$$\beta = \frac{1}{K}\left[\frac{M_g}{M_l} + \frac{1}{\rho_g}\right] = \frac{1}{K}\left[\frac{22{,}414\,Z}{M_l}\right]$$

where M_g = molecular weight of gas phase

M_l = molecular weight of liquid phase

ρ_g = density of gas phase at column temperature

Z = compressibility factor at column temperature and pressure

The K values obtained through this method compare well with published K values including the NGAA values. From the presentation "Vapor-Liquid Equilibrium Constants from Gas Chromatography Data" by S. T. Preston, Podbielniak, Inc., Chicago.

Stabilizer Problems on Computer

STRIPPER-STABILIZER equations have been developed for a digital computer so that each iteration forces the variables of the system closer to their true values. A rigorous solution can usually be obtained within a few trials. The general technique can be used to solve distillation, deethanization and other process problems. From the presentation "The Solution of Stripper-Stabilizer Problems by Use of Digital Computers" by C. R. McNeese, The Atlantic Refining Company, Dallas, Texas.

Plate-to-Plate Distillation Calculations

A program for plate-to-plate distillation calculations has been set up for a digital computer, which has advantages over previous methods. Unique features of the program are:

- Feed flash options to permit calculation of towers operating in sequence.
- Provisions for calculating non-refluxed towers
- A terminal stream adjustment technique with a high degree of reliability.

The technique can be adapted to any medium sized computer. Sample problems demonstrate the use of NGAA K values. They emphasize the wide range of distillation problems solved by this program. The rigorous procedure of Lewis and Matheson was selected over Thiele and Geddes method. From the presentation "Distillation Calculation on IBM 650" by R. N. Maddox and J. H. Erbar, Oklahoma State University, Stillwater.

NGAA Manpower Appraisal

Appraise Personnel by Setting Goals

Gerald F. Bassler
Continental Oil Company
Houston

IN ADOPTING a goal-setting approach to personnel appraisal, the supervisor is less concerned with what has happened in the past, but vitally interested in planning for the future. He continues to appraise performance just as he always has—the difference is now he appraises to help his employes achieve work goals previously established, rather than criticizing past performance. Appraisal becomes a means of reviewing progress, and counseling a means of encouraging improvement.

Some of the improvements which have already resulted from this technique are as follows:

Improved Performance—in one refinery the number of control lab tests were reduced by 16 percent releasing eight control chemists for other duties. Result: time and money saved.

Changed Attitude—in a marketing office the contractor sales representative had gone dead on his job. As a last resort his boss suggested that he set up some six month goals to accomplish. This man is now working nights and occasionally on Saturdays in order to accomplish his goals. Result: increased contacts and more business and—a better employe, and—a happier boss.

Increased Efficiency—an outlying warehouse was eliminated and three employes transferred as a result of a study made as part of the goal setting activity. This study which revealed inventory duplication, increased taxes, and misused manpower had been planned previously but never made. Result: manpower and money saved.

Past Performance. Prior to adopting the goal-setting plan, Conoco's appraisal and counseling program was a critical review of past performance followed by a review with the subordinate. However, many supervisors disliked having to report appraisal judgments to subordinates, particularly telling a subordinate that he was not doing well. This was true despite the belief that each subordinate has a right to know his boss' opinion so he can improve his own performance.

There was a general dislike on the part of supervisors of the "brainwashing" aspects of formal counseling interviews. They felt they did a more effective job through day-to-day coaching. While this is undoubtedly true from the supervisor's standpoint, it usually failed to provide opportunity for the subordinate to have his "day in court."

These and other problems caused many supervisors (as well as residents of the ivory tower) in and outside of Conoco, to critically examine *where we are*, and more to the point, *where we are going* in this business of appraising and reviewing job performance. That concern has resulted in studies on two fronts. One of these studies was conducted informally by supervisors themselves searching for a way to eliminate some of the current problems. The other has been a more intensive study conducted by social scientists and psychologists.

Significantly, both groups agreed on the following general conclusions.

1. A more positive approach was needed.

2. Accent performance—action related to work goals.

3. Place emphasis on joint (supervisor-employe) planning for the accomplishment of work-related goals.

4. Provide a more active role for the subordinate, through self-analysis and joint analysis of his progress toward mutually agreed upon targets.

5. Integrate self-development plans for improvement of job performance.

Ideas in Goal Setting. Goal setting as an approach to manpower appraisal (and personnel development) is based on some solid foundations. Without getting into research, the key ideas on which this system is based are:

1. People support what they help create.

2. Performance appraisal ought to deal with work results—not personality.

3. Changes which mean improved work results are the responsibility of the man himself.

This approach, in action, looks something like this.

1. Employe self-appraisal. The supervisor asks each employe to analyze his own job performance. This analysis considers six factors that are critical in getting results.

- His organization produces results.
- He operates efficiently.
- He makes realistic plans for the future.
- He works well with others.
- He develops his employes.
- He develops himself.

The subordinate is required to write down work improvement goals in applicable areas in specific and concrete terms, including target dates.

2. **Appraisal by superior.** At the same time as the employe appraises his own performance, the supervisor makes a review of the employe's job performance and writes up his ideas of what work goals are needed for new accomplishments or improved performance.

3. Setting workable goals. The supervisor reviews the employe's work targets and makes suggestions for revision based on his own appraisal of the subordinate's performance and needs for improvement. The result of this discussion is a set of work goals and training plans (with target dates), which have been mutually agreed upon by the employe and his supervisor.

4. Progress review. From time to time, the supervisor reviews progress toward these goals with his employes and counsels with them. He wants to "keep them on the beam" in making the improvements necessary to reach their objectives. At the end of the "target period" (a year, six months, or other appropriate period of time), the supervisor and subordinate review accomplishments in terms of targets and draw up a new set of plans for the next period.

Another point to consider is that this goal-setting approach calls for the employe (with counsel from his boss) to set goals, plan ways of achieving these goals, and set up a schedule of action. Thus, the subordinate gains experience in assuming more active responsibility in the management of his own operations.

Since this method differs from the old "telling a man where he stands" approach, the man finds out for himself where he stands. Because of this, it is easier for him to accept the information and do something about it.

Original presentation before NGAA, Dallas, April 22.

Interstate Switches to New Method

IN ITS EMPLOYE evaluation program, Interstate Oil Pipeline Co. at one time used what is often referred to as the "open end" rating scale, many variations of which are commonly in use in industry today. It attempts to rate a number of behavior traits such as cooperation, initiative, speed, accuracy, etc., usually on a five-degree scale—excellent, good, average, fair, and poor.

All Excellent. The appraisals of a group of non-supervisory office employes made by this method for a period of several years were studied. The employes were typical; the supervisors making the appraisals were honest and sincere in endeavoring to evaluate each employe's performance for counseling purposes. Nevertheless, the results when scored and plotted, showed the significant fallacy of this type of appraisal.

All but one of the group were appraised at the "excellent" end of the scale—only one employe fell as low as "good."

It stands to reason that, in such a group of employes, each one is not "six feet tall." The performance traits of people are not as distributed, but follow a more normal pattern

of dispersion. That is, a few very good stand-out performers at the high end; a few "least good" performers low on the scale. However, the great majority—68 percent in fact—fall in the broad middle area on the scale.

Form Errors. With the knowledge that he will later use his evaluation as a basis for discussing an employe's performance, it is difficult for a supervisor to be completely objective, using this method. The form itself invites the assumption and generalization that all these behavior traits are equally related in equal quantities.

Also the form fosters a number of human errors in judgment, such as:

1. The forgetting errors. The tendency to generalize about the behavior traits listed, without relating them specifically to the individual employe's job performance.

2. The "sequential" error. Or tendency, when appraising a group, for the supervisor to subconsciously become aware he is marking all high and adjust his appraisal of the next employe accordingly.

3. The dramatic incident. The tendency to recall some instance in an employe's work life and base the appraisal on this recollection.

4. The "halo" error. The charitable tendency to appraise a group, or individuals within a group, better than they actually are; also, the obvious opposite.

5. The "prejudice" error. Intentional and unintentional.

There are a number of others.

New Method. Subsequent appraisal of this same employe group, using an entirely different method and form, was more valid and objective, as indicated by the more normal distribution of individual members of the group in the "fair," "average" and "good" ranges.

The supervisor appraising an employe by this method does not "rate" him on performance behavior traits, but rather attempts to describe him in terms of his job performance. On a form containing 28 blocks of 5 descriptive statements, he attempts, in each block, to pick the descriptive statement most like the employe, also the statement which least describes him. This method helps the appraiser remember and reduces the halo, prejudice and dramatic incident influences.

A comparison of the appraisals of individual supervisors using the "open end" form versus the descriptive type method indicates the latter helps the rater to discriminate more accurately between employes. Also, in each employe group, there was at least one instance, often more, in which the rating of an individual employe differed dramatically, indicating gross inconsistency of appraisal.

From "Objectivity in Employe Appraisal," by W. L. Bassman, Interstate Oil Pipe Line Co., Shreveport.

How Atlantic Does It

ATLANTIC REFINING'S personnel appraisal plan includes a series of personnel tests, an interview, a personal data questionnaire, and an appraisal by a panel of three to five members. The results of the appraisal are discussed by the immediate superior with the "appraisee." From this discussion, a mutually agreed-upon development plan is outlined for the immediate future.

In general, the plan has promoted morale among those included. The individual appraised has been assured that his performance will be reviewed carefully, and he will be advised of "where he stands." He has seen, in many cases, the development of a better climate of mutual confidence and communication between him and his supervisor.

Self Analysis. The development phase takes many forms. It has been found to begin in a self-development program early in the operation of the plan with the individual concerned. His self-analysis while completing the personal data questionnaire, results many times in the basis for the beginnings of a self-development program. Such action is further encouraged through the performance and development interview between the appraisee and his superior following the appraisal.

Also supervisors acting as appraisers tend to see the various facets of their own performance in a different light as they appraise their subordinates, and take direct action through a self-development program of their own.

Coaching by the superior has been found to be one of the most valuable development "tools." Placement and job rotation supply some of the development needs for broadening experience and give a supervisor an appreciation of the complexities inherent in certain technical fields and geographical areas.

Annual Review. The Management Personnel Inventory and Development Plan is not static. Through the development efforts, continual improvement is being made in the management ranks. This is assured through a close follow-up by the president of Atlantic. Annual written and oral reports are made to the president by the vice-presidents, reviewing the status of the program, the manner in which needs are being fulfilled, and the replacement of unsatisfactory performers. Without such backing by the top management, no such plan can achieve the best results.

From "Results of Atlantic's Appraisal Program," by Robert A. Jones, Atlantic Refining Co., Dallas.

##

Which Acetylene Removal Scheme Is Better?

Here are the economics of absorption versus hydrogenation for removing acetylene from rich ethylene streams

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Monsanto Chemical Company
Texas City, Texas

WHICH METHOD of acetylene removal (absorption or hydrogenation) is the most economical? One method is economically superior to the other depending upon the following variables: plant size, by-product value of acetylene, and acetylene made per 100 pounds of ethylene produced. Boundaries on the conditions which favor hydrogenation and destruction of the acetylene and those which favor absorption and recovery of the acetylene for sale will be established in this article.

Acetylene, a minor by-product of ethylene production, is usually removed from the product ethylene to meet specifications set by the consumer. For example, ethylene converted to polyethylene must be essentially acetylene free.

Two methods are in use for acetylene removal from rich ethylene streams. One is absorption in a selective solvent such as dimethyl formamide. The other is catalytic hydrogenation of acetylene. Both methods are used commercially; both are capable of removing acetylene from ethylene to meet the most stringent specifications.

Major advantages of the acetylene absorption method are: recovery for sale of by-product acetylene and negligible destruction or loss of product ethylene. A major disadvantage is the higher capital required.

The major advantage of the acetylene hydrogenation method is the

TABLE 1—Premises of Study

Hydrogenation of Acetylene	
Pressure	= 150 PSIA
Temperature	= 325°F
Space Velocity, Std Cu Ft Gas/Cu Ft Catalyst	= 2000
Acetylene in Exit Gases	= <10 ppm
Ethylene Loss	1%
Catalyst Life	2.5 Years
Pressure Drop	10 PSI
Absorption of Acetylene	
Pressure	= 400 PSIA
Temp of Solvent In	= 10°F
Acetylene in Exit Gases	= <10 ppm
Ethylene Loss	Nil
Solvent Loss	10% of initial charge per year
Pressure Drop	2 PSI

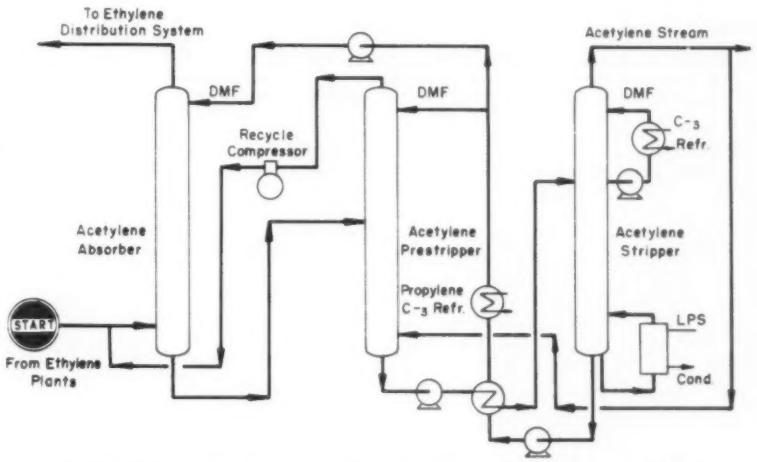

FIGURE 1—Equipment arrangement for acetylene recovery using DMF.

TABLE 2—Investment Summary*

Ethylene Rate Million Lb/Yr	Absorption of Acetylene Thousands of Dollars			Hydrogenation of Acetylene Thousands of Dollars			Difference Thousands of Dollars
	Mfg.	Non-Mfg.	Total	Mfg.	Non-Mfg.	Total	
50	260	65	325	120	30	150	175
100	390	92.5	482.5	190	42.5	232.5	250
150	500	125	625	250	62.5	312.5	312.5
200	590	147.5	737.5	320	80	400	337.5
250	680	170	850	370	92.5	462.5	387.5
300	760	190	950	420	105	525	425.0

* Zero Working Capital Assumed.

lower capital required. Major disadvantages are: destruction of product ethylene about 1 percent being hydrogenated to ethane and destruction of by-product acetylene.

HYDROGENATION

For information on catalytic hydrogenation of acetylene, a recent article by Reitmeier and Fleming has been used.[1] The cracked gas is hydrogenated after compression and prior to drying if butadiene destruction is desired. If butadiene is a valuable by-product, hydrogenation is conducted after drying and C_4 removal but prior to methane and hydrogen removal.

The efficiency of hydrogenation of the cracked gas in the dry state is assumed equivalent to that when wet. This assumption is made on the basis of claims of catalyst manufacturers and not on the basis of knowledge of actual plant performance.

If hydrogenation in the absence of steam results in excessive catalyst fouling or poor selectivity, then the comparative economics of absorption when using C_4 or heavier feed stock become much more favorable than shown.

ABSORPTION

For information on absorption of acetylene, a recent article by the author has been used.[2] Acetylene is removed from the ethylene prior to its distribution to consumers. DMF (dimethyl formamide) is used as a selective solvent. A high pressure absorber, a combination atmospheric absorber-prestripper, and a stripper are used.

Comparison and Economics. Premises were first set (See Table 1). A flow diagram of each process was prepared (See Figures 1 and 2). An equipment list was prepared for each of the processes and equipment costs estimated at an ethylene production level of 150 million pounds per year. A Lang factor of 4 was assumed for both processes to obtain total manufacturing capital from equipment costs. Manufacturing capitals were calculated for both processes at operating rates of 50, 100, 150, 200, 250, and 300 million pounds per year by equating the ratio of rates raised to the six-tenths

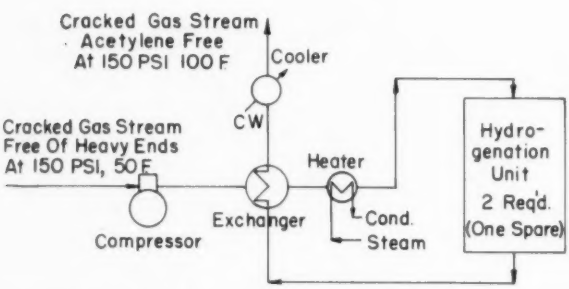

FIGURE 2—(above) Hydrogenation of acetylene from ethylene rich stream uses this equipment arrangement. Note: Facilities for regeneration-steam heater, hydrogen cylinders—not shown.

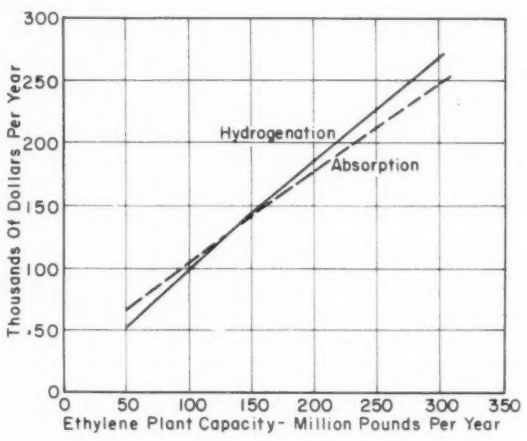

FIGURE 3—(right) Shows estimated manufacturing costs of acetylene removal versus ethylene production rate.

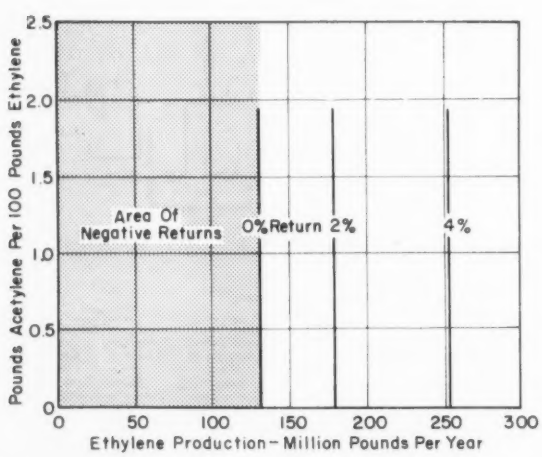

FIGURE 4—With acetylene value of 0¢/pound these are the rates of pretax returns on the extra investment required to build the absorption plant versus quantity of acetylene made.

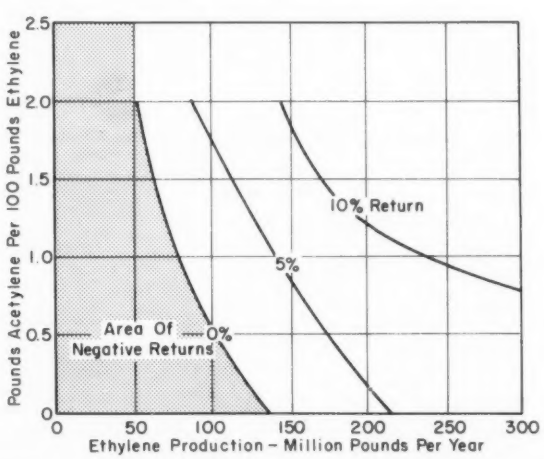

FIGURE 5—With acetylene value of 1¢/pound these are the rates of pretax returns on the extra investment required to build the absorption plant versus quantity of acetylene made.

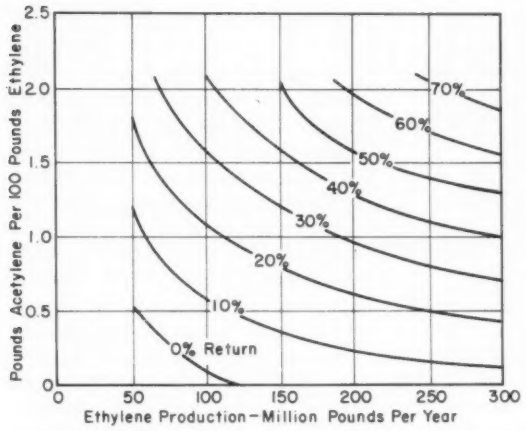

FIGURE 6—With acetylene value of 5¢/pound these are the rates of pretax returns on the extra investment required to build the absorption plant versus quantity of acetylene made.

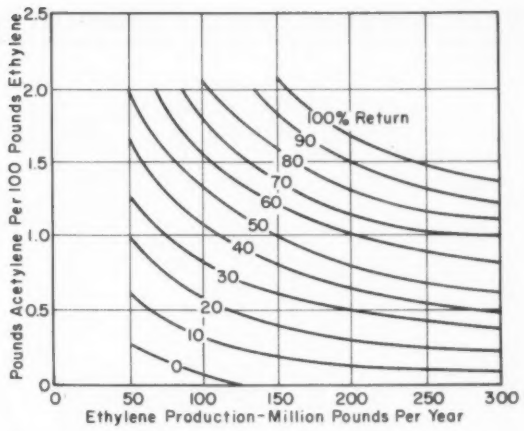

FIGURE 7—With acetylene value of 10¢/pound these are the rates of pretax returns on the extra investment required to build the absorption plant versus quantity of acetylene made.

power to the capital ratios. Thus:

$$\left(\frac{50\ \text{M}\#/\text{yr}}{150\ \text{M}\#/\text{yr}}\right)^{0.6} = \frac{\text{Mfg. Capital at } 50\ \text{M}\#/\text{yr}}{\text{Mfg. Capital at } 150\ \text{M}\#/\text{yr}}$$

In this calculation, duplication of equipment was considered and capital adjustment were made when the use of the six-tenths factor did not apply. The initial catalyst charge in the hydrogenation case was capitalized and its capital was ratioed directly to production rate. The initial solvent charge in the absorption case was capitalized and its capital was ratioed to production rate by use of the six-tenths factor. Calculated manufacturing capitals are tabulated in Table 2.

Note that the manufacturing capital is proportional to the ethylene make and assumed independent of acetylene make. This is quite reasonable as both the absorption and hydrogenation systems are sized on

TABLE 3—Manufacturing Costs of the Absorption & Hydrogenation Systems at the 150 M #/Yr Ethylene Production Rate

	Absorption of Acety. #/Yr	Hydrogenation of Acety. #/Yr
Solvent Losses	6,000	
Catalyst (2.5 Yr Life)	.....	16,000
*Ethylene Destroyed @ 4¢/#	.....	60,000
Utilities	38,000	20,500
Repairs	25,000	12,500
Misc. Directs: Laboratory, Royalties, Etc.	17,500	4,000
Depreciation, Taxes, Ins., Etc.	60,000	30,000
Total	146,500	143,000

* Ethylene is valued at 5¢/# and ethane at 1¢/#. Every pound of ethylene converted to ethane represents a 4¢ loss.

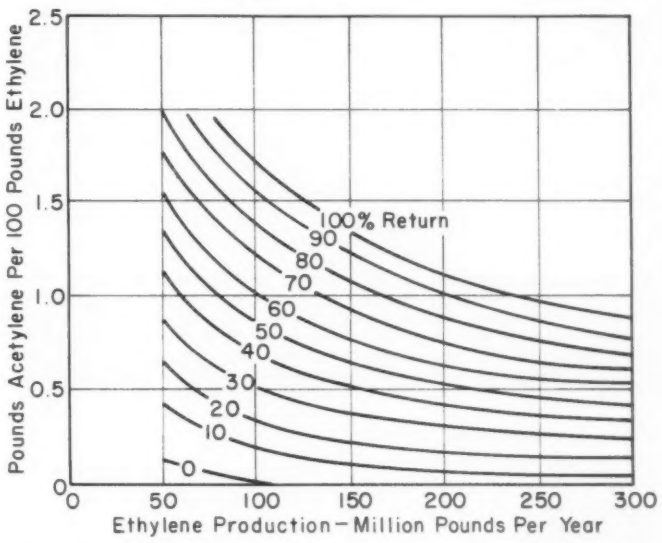

FIGURE 8—With acetylene value of 15¢/pound these are the rate of pretax return on the extra investment required to build the absorption plant versus quantity of acetylene made.

TABLE 4—Rate of Return Before Taxes—Absorption Versus Hydrogenation

Basis:	
Ethylene production	= 150,000,000 lb/yr
Acetylene make	= 1-lb acetylene per 100 lb ethylene produced
Acetylene value	= 10¢ lb
Investment: (from Table I)	
Absorption System	625,000
Hydrogenation System	312,500
Difference	$312,500
Gross Income from Sales:	
Absorption System	150,000
Hydrogenation System	0
Difference	$150,000
Manufacturing Costs:	
Absorption System	146,500
Hydrogenation System	143,000
Difference	$ 3,500
Net Income before Taxes:	
Absorption System	$ 3,500
Hydrogenation System	−143,000
Difference	$416,500

Rate of Return before Taxes on Additional Investment in Absorption Facilities: 46.75 per cent

Which Acetylene Removal Scheme Is Best?

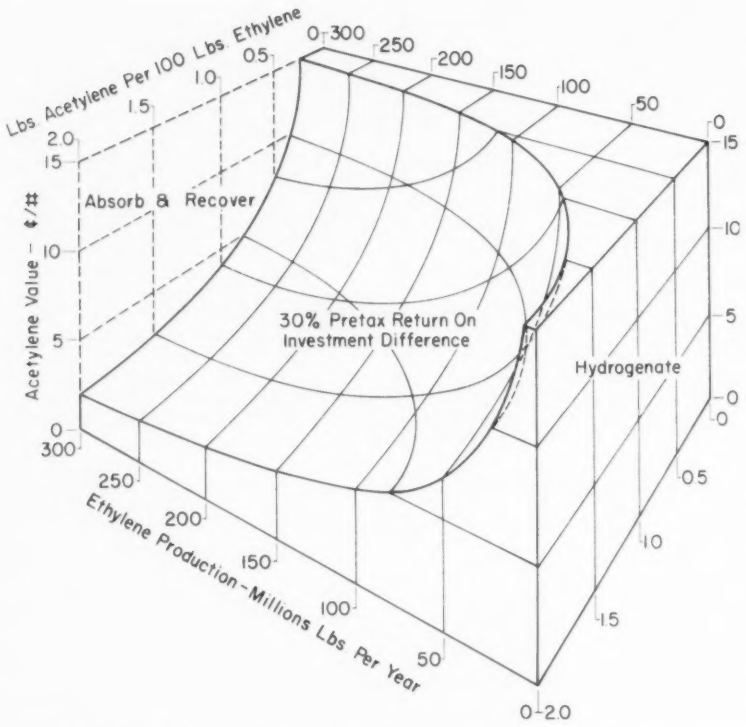

FIGURE 9—Surface represents a 30 percent pretax return on extra investment required to build the absorption system. Solid portion of figure represents conditions favorable to hydrogenation. Cut out portion of figure represents conditions favorable to absorption and acetylene recovery. This figure indicates that hydrogenation is the preferred method of acetylene removal when acetylene make is low, has little value or when ethylene plant is small. Absorption is preferred when acetylene make is high acetylene at least as valuable as ethylene, and ethylene facility is large.

About the Author

W. H. Stanton is manager of engineering planning for Monsanto Chemical Co., Texas City. He received a B.S. degree in chemical engineering from Purdue University in 1942 and joined Monsanto the same year. He has worked primarily as a process engineer in plant design at St. Louis, Springfield, Mass.; Columbia, Tenn.; Marshall, Texas; and Texas City, where he has been since 1951. Stanton has worked in many of Monsanto's larger petrochemical plants and is presently in project evaluation and facilities planning.

total gas flow, not acetylene concentration in the gas.

An allowance for non-manufacturing capital of 25 percent of manufacturing capital is made. This represents supporting investment in steam, power, shops, offices, etc. Zero working capital is assumed. Capitals are totaled and a difference between the investment in absorption and hydrogenation is shown.

Next, manufacturing cost estimates were prepared. The manufacturing cost consists of raw material costs such as solvent or catalyst and ethylene losses; direct costs, such as laboratory charges, royalties, repairs, etc.; indirect costs, such as, depreciation, insurance, taxes, etc. Typical manufacturing costs at the 150 million pound per year ethylene production rate are shown in Table 3. Estimated manufacturing costs of acetylene removal versus ethylene production rate are plotted in Figure 3.

Economic Comparison. We now have the required ingredients to make an economic comparison of the two processes over wide ranges of ethylene production. The problem is when to hydrogenate or when to absorb the acetylene. Put another way, when can we justify the additional capital required to construct an acetylene absorption system?

One way to answer the question is to plot as independent variables: acetylene production rate, acetylene make, and acetylene value and show as the dependent variable the return on the extra investment required in absorption facilities. Figures 4, 5, 6, 7 and 8 show these relationships at acetylene values of 0, 1, 5, 10 and 15 cents per pound. Rate of return before taxes is calculated for a typical case to illustrate the meaning of the term.

To gather the information in one plot, Figure 9 was prepared using a 30 percent return before taxes on differential investment as the dividing surface between hydrogenation and absorption.

A study of Figure 9 would indicate that hydrogenation is the preferred method of acetylene removal when the acetylene make is low, when the acetylene has little value, or when the size of ethylene facility is small. When producing ethylene from light feed stock, ethane, refinery gases or even propane, at rates below 100 million pounds per year with by-product acetylene valued at less than 5 cents per pound, the use of acetylene hydrogenation is preferable.

On the other hand, absorption is preferred when acetylene make is high, when the acetylene has at least ethylene value, and when the size of the ethylene facility is large. When producing ethylene from C_4 or heavier feed stocks at rates of 150 million pounds per year or above, with acetylene valued at more than 5 cents per pound, the use of an acetylene absorption system is preferred.

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[1] Reitmeier, R. E. and Fleming, H. W. Chem. Eng. Progress, Vol. 54, No. 12, p. 48, Dec. (1958).

[2] Stanton, W. H. Petroleum Refiner, Vol. 38, No. 31, p. 209, 1959.

API Panel Studies Corrosion Control Tests

Panel survey reveals sloppy procedures in making analytical tests for corrosion control

THOSE CHARGED with corrosion control of refinery equipment often take analytical results for granted. The cost of analytical tests is far from insignificant. A routine test may cost five dollars or more. If such a test is run once-a-shift, each day of the year, this is an expense of over $5,000 each year. Multiply this by the number of tests involved and the total justifies concern.

In 1957, the API Subcommittee on Corrosion formed a panel to investigate analytical techniques and procedures for control of corrosion. The long-range objective was to inform the industry on the application of analytical methods.

This information, although gathered under the auspices of the API, should not be construed as recommending or suggesting any standard or generally accepted practice for the industry. Based on the replies received from two surveys of 21 companies, the panel has drawn the following conclusions:

- For the three analytical tests under study, there are no universally accepted procedures in the industry. There is, however, agreement as to general type of test to use: electrometric pH, combustion methods for total sulfur in crude, and colorimetric procedures for iron content of process water.
- The corrosion engineer needs to be more familiar with special precautions required when sampling or carrying out these tests, and with the types of materials that interfere with the results.
- Corrosion engineers apparently use various analytical tests for corrosion control, but there appears to be some uncertainty that the significance of the test results are always known.
- The panel feels the following advice to corrosion engineers is in order:

a. Know your tools. Interpretation of results depends largely on a knowledge of test procedure, accuracy of result, sampling technique, and whether or not the sample is representative of the condition being tested.

b. Use analytical tests. Since "common sense" procedures in sampling and running the tests appear to be the major concern, "common sense" should also be used in requesting analysis and interpreting results.

c. Evaluate worth of analysis. Unless the person requesting tests is in a position to state the significance of a result, there is no point wasting time and money in obtaining a number in the first place.

d. Consider economics. Analytical tests are costly; request them only when needed.

Initial Survey. What analytical procedures are being used for corrosion control of petroleum refining equipment? This had to be established by a survey. For this purpose, inspection techniques not requiring laboratory work were eliminated from consideration. Twenty-one cooperating companies furnished information that may be summarized as follows:

1. Forty-six types of analytical tests being used to control corrosion of petroleum refining equipment are listed in Table 1.

2. The analytical tests used most frequently for this purpose by the petroleum industry are listed below:

a. pH Determinations
b. Scale and Deposit Analysis
c. Sulfur and/or Hydrogen Sulfide Content
d. Metal Analysis of Process Water

3. Analytical tests are used to control corrosion in all types of refinery equipment. In addition to the 23 major refinery units specified, 28 miscellaneous locations were mentioned as requiring at least one form of analytical technique to control corrosion.

4. Considering the total number of analytical tests used, the refinery locations which receive the most attention from a corrosion standpoint are listed below:

a. Crude Distillation
b. Catalytic Cracking
c. Catalytic Reforming
d. Cooling Water Systems
e. Boiler Feed Water Systems

TABLE 1—Types of Analytical Tests Being Used to Control Corrosion of Petroleum Refining Equipment

Analysis of Utility Waters	Painted-Can Test
Bacteria Content	pH Determinations
Carbon Dioxide	Radio-Activity Measurements
Chlorine or Chloride Content	Residual Sodium Sulfite Content
Chromate Content	Salt Content
Corrosivity of Crude (HCl Evolution)	Scale and Deposit Analysis
Corrosivity of Crude (H_2S Evolution)	Specific Acid Concentration
Corrosivity of Crude (Not Specified)	Specific Alkali Concentration
Cyanide Content	Specific Salt Concentration
Electrical Resistivity Probes	Steam Purity
Fluoride Content	Sulfate Content
Fuel Ash Analysis	Sulfides Content
Hydrogen Probes	Sulfur Content
Hydrogen Sulfide Content	Sulfur Dioxide Content
Inhibitor Concentration	Sulfur Trioxide Content
Mercaptan Content	Suspended Solids of Process Stream
Metal Coupons or Comparators	Suspended Solids of Process Water
Metallographic Examinations	Thiocyanates Content
Metals Analysis of Process Stream	Thiosulfate Content
Metals Analysis of Process Water	Total Alkalinity of Boiler Water
Naphthenic Acid Content	Total Dissolved Solids of Boiler Water
Nitrogen Content	Water Content
Organic Acid Content	
Oxygen Content	

Second Survey. Many times analytical results may be misinterpreted by corrosion engineers primarily because the results are not fully understood. Therefore, to develop information for the corrosion engineer which he can use to better interpret results of analytical tests, a second survey was conducted. In this regard, three of the most widely used tests—pH, total sulfur, and iron content—were selected for further study. The petroleum companies were requested to supply the following information, limited to crude distillation units, on these three tests:

- Methods in use currently and their accuracy.
- Special precautions when sampling or carrying out these tests.
- Experience or knowledge of materials that interfere with these tests.
- An explanation, from a corrosion standpoint, of the significance placed on the test result.

The most pertinent information

supplied from this second survey by 21 companies revealed the following:

pH Determinations. *All* companies use pH determinations in connection with corrosion control of crude units. In most cases, more than one type of pH procedure is being followed. Electrometric pH determinations are employed most widely by 90 percent. Colorimetric procedures are used by about 40 percent of the companies and pH paper tests are made by unit operators for checking purposes in about 30 percent of the reported cases.

Most consider the accuracy of electrometric determinations to be from 0.05 to 0.1 pH units; the colorimetric methods being less accurate, from 0.1 to 0.5 pH units.

Clean equipment, properly maintained, checked and calibrated are precautions most companies recommend for electrometric determinations. Information given in API Method 707-53 and ASTM Methods E 37, E 70 and D 1293 should be understood. Colorimetric methods, being less accurate, require normal good laboratory technique such as checking color and clarity of standards and immediate color comparisons.

In general it was felt that no sampling precautions are necessary other than "common sense" or standard accepted techniques, such as obtaining representative samples in clean containers. It should be recognized, however, that the pH of a sample might change, usually as the result of loss or absorption of gases. Therefore, precautions must be considered depending on the application of results. For control application, a precise value is not always necessary; values obtained under such conditions should not be reported for comparison with exact values from other sources.

Interfering materials most often reported for electrometric methods are:

- Small amounts of oil which coat the electrode.
- Excessive solids.
- Iron, inhibitors and other compounds which might plate out on or poison the electrode.

Dissolved H_2S, turbidity and excessive natural color cause trouble with the colorimetric procedures. It should be pointed out, however, that the interfering materials listed for the electrometric methods present no difficulties if the equipment is properly maintained.

For corrosion control of crude units, pH determinations are made on desalter waters or any location of water build-up, such as exchangers, reflux drums, overhead accumulators, separators, or receivers. Past refinery experience, more than engineering technology, apparently dictates what pH level is most satisfactory and economical. In overhead water a wide range, 6.5-9.0 pH units, is used to control corrosion. It is reported that iron is attacked rapidly below 6.5 pH and, in one case, above 8.0 pH loss of copper from admiralty tubes was encountered.

Total Sulfur. In reply to the survey, most companies gave procedures for total sulfur for both crude oil and gasoline. However, total sulfur content of gasoline is not being used for corrosion control in crude distillation units. Less than 30 percent of the companies use total sulfur of crude oil for corrosion control in crude distillation—and most of these do not use the test as routine control.

Total sulfur contents, by a combustion method (such as the oxygen bomb method), are determined on the charge to the crude unit. The oxygen bomb method is reported to be the most accurate, less than ± 0.1 percent wt. sulfur. Precautions and the effect of interfering materials, as stated in ASTM D 129 method, are generally believed adequate.

The significance of total sulfur for corrosion control was not made clear by those companies claiming to use it. Generally this value is a useful aid in selecting proper processing steps so that corrosion protection is provided when needed. Some use total sulfur to anticipate corrosion rates or high-temperature sulfur corrosion. While some feel that higher values generally mean more corrosion, one company reported that "sweet" West Texas crude containing 0.5 percent wt. sulfur is far more corrosive than North or East Texas crude containing an equal quantity of sulfur. There appears to be some agreement that total sulfur correlates corrosion data to alloy requirements.

Iron Content of Process Water. Iron content of process water is used widely, by 75 percent of the companies, as a corrosion control technique in crude units. The significance of the test varies considerably among those using it; in many cases this is not a routine control method.

Colorimetric methods are used by most companies, the *o*-phenathroline method being most popular. The reported accuracy of the tests in use varied considerably. The panel believes this is due to the many materials which can interfere with the test. Metals such as Ag, Co, Cr, Cu, Ni, and Zn, as well as citrates, molybdates, oxalates, tartarates, phosphates, and other materials may interfere. It appears, however, that the important precautions necessary in determining the iron content of process waters are well covered in standard procedures for the methods (ASTM D 1068 and D 810 Methods, for example).

Samples of water tested for iron content are usually obtained at crude tower overhead receivers, accumulators, and/or reflux drums. Generally it is felt that no special sampling precautions are necessary other than to obtain representative samples in clean containers (ASTM D 510 Method may be used as a reference).

There was no general agreement on the significance of iron content for corrosion control. Many companies apparently use iron content to help establish the success of corrosion control programs. A number of companies have experienced good corrosion control when iron contents of overhead waters are below 10 ppm. When determined along with pH, iron contents are used to adjust inhibitor and/or neutralizer rates or for evaluating inhibitor and/or neutralizer efficiency. Some companies regard iron content as a direct measure of corrosion rate, while other companies have not been able to find such a correlation.

ACNOWLEDGMENT

This summary report of the Panel on Analytical Techniques and Procedures for Control of Corrosion was made to the API Subcommittee on Corrosion, Committee on Refinery Equipment. The panel members are: E. B. Backensto, Panel Leader, J. E. Carney and H. F. McConomy.

Infrared Analyzer Controls Absorber

Higher ethylene recovery and lower methane absorption were gained in this demethanizing absorber. Analyzer controls heat input to reboiler

G. M. Hicks and D. D. Livingstone
Polymer Corporation Limited
Sarnia, Ont.

USING AN infrared analyzer has increased efficiency of a demethanizing absorber at Polymer Corporation's Sarnia plant. The analyzer set-up increases ethylene recovery and minimizes methane absorption in the light ends recovery unit. It's used to control heat input to the reboiler.

The Process. The light ends recovery unit recovers both ethylene and a mixed butane-butylene cut for feed stocks in a synthetic rubber plant. The feed to this unit is produced by catalytic cracking in nearby oil refineries. It consists of both gas and liquid streams containing all the C_4 and lighter hydrocarbons plus nitrogen, hydrogen, carbon monoxide, carbon dioxide and hydrogen sulfide, an appreciable proportion of C_5 hydrocarbons and some C_6 hydrocarbons. The feed streams are treated to remove hydrogen sulfide and carbon dioxide, and then dried before entering the series of fractionating towers. Figure 1 is a flow diagram of the unit showing the series of fractionating towers used to separate the various components.

The demethanizing absorber is the first in the series of fractionating towers and is used to recover the ethylene and heavier components from the feed by absorption in a C_4-C_5 cut absorption oil. This absorber is a 42-tray bubble cap tower operating at 500 psig. The bottom 12 trays act as a stripping section with a reboiler providing heat to strip methane from the bottoms product. The gas feed enters the tower just above the stripping section. The liquid feed enters 14 trays above the gas feed and acts as an absorption oil. At the top of the tower, 16 trays above the liquid feed inlet, an absorption oil of C_4 and C_5 cuts, produced in a subsequent tower, enters the system. All three feed streams, gas feed, liquid feed, and absorption oil have been cooled to 0 F.

The Control System. A simplified drawing of the control system is shown in Figure 2. The controls for the tower, as originally designed, include:

- A pressure controller regulating the flow of overhead gas
- A flow controller regulating the flow of absorption oil
- A flow controller regulating the

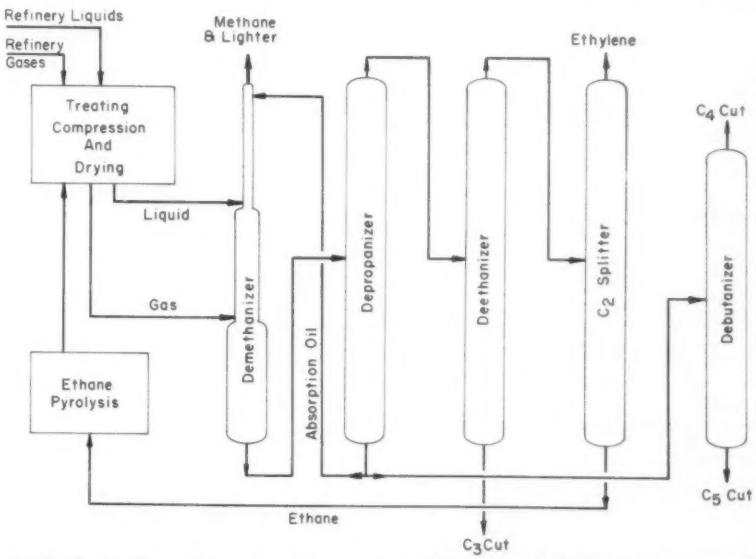

FIGURE 1—Flow scheme for recovery unit: Ethylene and B-B cut are recovered from cat cracker off-gases.

flow of bottoms product. This instrument is manually reset to maintain the bottoms level which is recorded on the same instrument chart

- A temperature controller regulating the bottoms temperature by resetting a flow controller in the steam line to the reboiler
- The usual number of temperature recorders and pressure gages and an infrared analyzer to monitor the methane content of vapors at the fifth tray from the bottom of the tower. This analyzer uses a sample from the fifth tray because here the methane content is approximately 10 mole percent whereas in the bottoms stream the content is approximately 0.5 mole percent and more difficult to analyze.

Flow of gas feed to the tower is not controlled but depends entirely on the production rates from catalytic cracking units at nearby refineries and both flow rates and composition vary continuously over wide ranges. Flow of liquid feed also depends on refinery production rates but surge drums ahead of the absorber permit use of a flow controller provided it is manually reset every hour or so. When one of the catalytic cracking units shuts down or starts up there are very sudden and drastic changes in both flow rates and compositions.

The purpose of the control system is twofold: to achieve maximum ethylene recovery and to maintain a minimum methane content in the bottoms stream. The reason for wanting maximum ethylene recovery is self evident. There are two reasons for maintaining low methane content in the bottoms. Subsequent fractionation recovers any methane along with the ethylene product and there are ethylene purity specifications to be met. In addition, excessive amounts of methane, when concentrated in the overhead of subsequent towers, will prevent complete condensation of reflux and result in tower upsets. Excessive stripping in the absorber will reduce the methane content of the bottoms but overload the absorption section and cause high ethylene losses overhead. Excessive absorption oil will ensure high ethylene recovery but overload the stripping section and cause high methane concentrations in the bottoms.

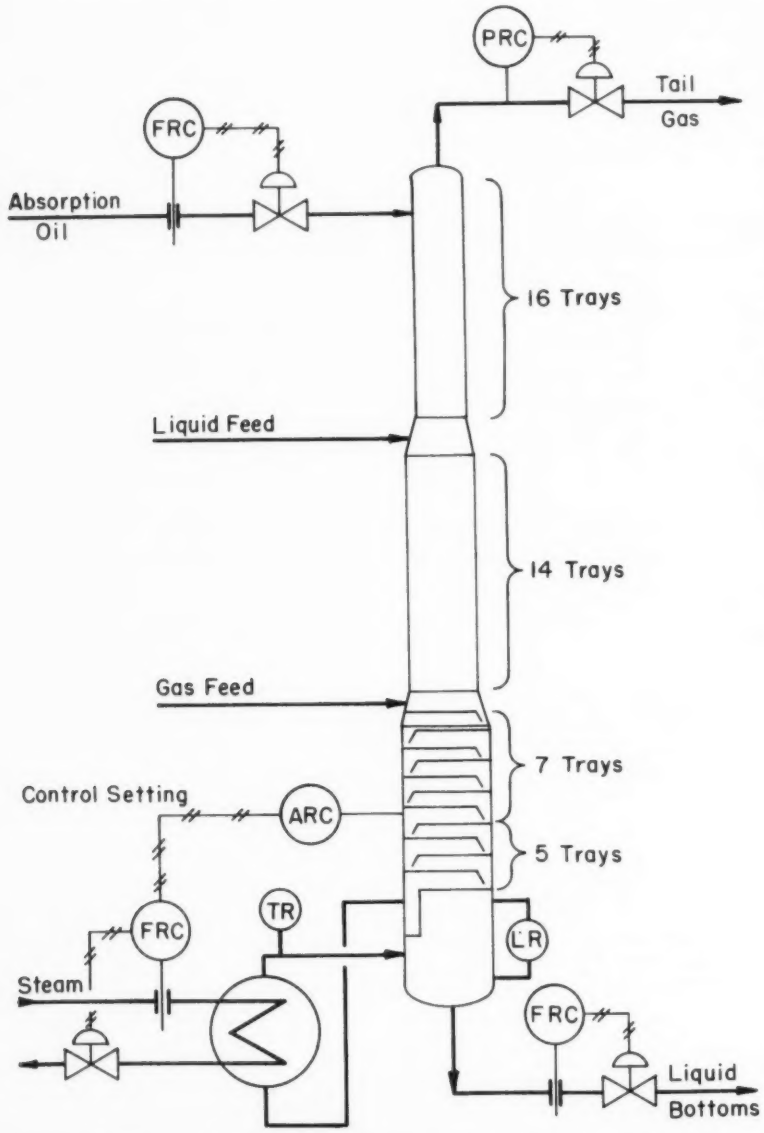

FIGURE 2—Control system for demethanizing absorber maximizes ethylene recovery and minimizes methane content in bottoms.

The Control Problem. The principle on which the control system was to operate was conventional. The pressure controller would hold the tower pressure steady, the absorption oil flow controller would be set at the lowest flow which would ensure adequate ethylene recovery, and the temperature controller would set the heat input to the stripping section at a rate which would maintain the bottoms temperature constant at the value where the methane content of the bottoms was satisfactory. This principle is fine for a two component separation and quite satisfactory for even a multi-component system provided that the composition of the ethylene and heavier fraction does not change and bottoms temperature is a true indication of methane content. Unfortunately, operations at the adjacent refineries were such that the C_5 and C_6 content of the stream varied over a very wide range and the temperature controller was completely unsatisfactory.

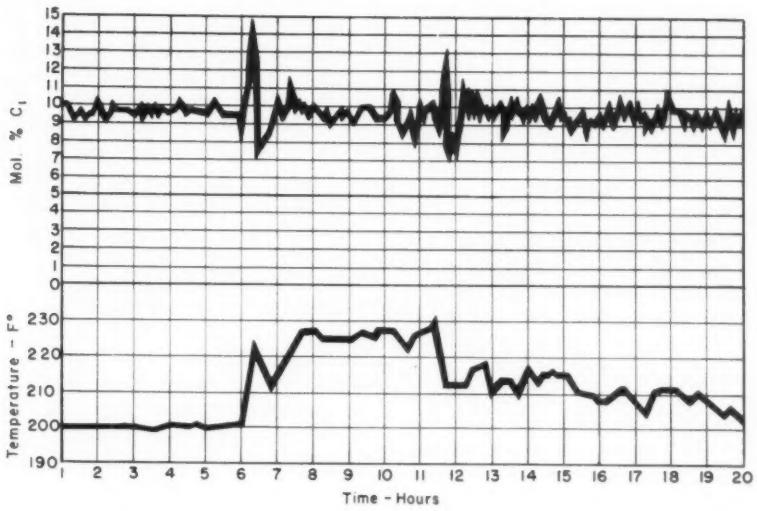

FIGURE 3—Methane content and temperature in absorber bottoms: Sharp temperature increase at 6 hours is due to C_3 increase from 5 to 20 mol percent.

When the C_3 content increased and the temperature controller held the bottoms temperature constant, the methane content of the bottoms then had to increase. If, for example, the C_3 content increased from 10 mole percent to 20 mole percent, the methane content more than doubled and this in turn caused trouble in the other fractionating towers. The capacity of the C_2 splitter condenser was reduced to less than half its normal value with resulting loss of reflux.

The infrared analyzer monitoring the methane content of the fifth tray vapors was installed to assist the operators in resetting the bottoms temperature. In practice the methane content varied so rapidly that the operators could not keep up with it and the only way the tower could be operated was to set the temperature high enough that the methane content never increased above the desired value. Most of the time the temperature was too high and there was excessive stripping. The average loss of ethylene overhead was 2 or 3 times the design value.

The Analyzer-Controller. Several weeks after the start-up of this new recovery system the very rough operations began to settle down under the control system described above but the ethylene losses were severe. The infrared analyzer had at this time been in service only a few weeks but appeared to be operating successfully. Since this was analyzing for the component that was to be controlled in the bottoms stream, the next step was to use the analyzer as a controller. A control unit was added to the analyzer recorder and this was used to replace the temperature controller resetting the flow of steam to the reboiler.

The particular analyzer used in this installation was a positive absorption type unit calibrated to give a full scale reading of 30 percent methane. Operation of this type analyzer is well described in the literature.[2,3,4,6]

The filter cell and detector cell are peculiar to this installation. The detector cell was filled with methane, the filter cell with propylene.

The sampling system used is shown in Figure 4. The sample is drawn from the tower at 500 psig and is immediately reduced in pressure to 50 psig by means of an orthodox reducing valve. The sample line then runs to the analyzer house and once inside the house is reduced again to approximately 2 psig by means of a constant differential relay. Before this reduction, a bleed stream is taken off to cut down to a minimum the dead time involved in sampling. This bleed is vented. The sample then runs through a sample filter and to the sample manifold where it is admitted to the analyzer by means of the sample solenoid valves. The used sample is finally vented to atmosphere. It will be seen from the diagram that in addition to the bleed at the 50 psig pressure level, there is another low pressure bleed in parallel with the analyzer in the analyzer house. The zero and full range standardizing samples are admitted to the sample manifold by means of single solenoid valves as required. The zero sample consists of analytically pure nitrogen while the full range sample is a 26.5 percent mixture of methane in nitrogen which produces a reading of 93 on the 0 to 100 scale.

What's mounted outside the control room (the pick up station, sample solenoid valves, standardizing samples and reducing valves) is housed in a steam-heated meter house which measures approximately 2½ by 2½ by 8 feet. All sample lines are steam traced and insulated.

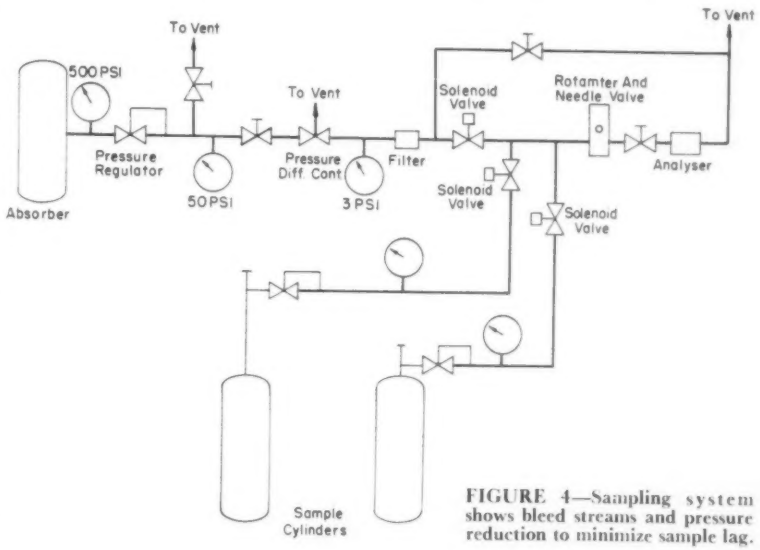

FIGURE 4—Sampling system shows bleed streams and pressure reduction to minimize sample lag.

The recorder, control panel and amplifier are housed in the control room.

The analyzer is checked for zero and full scale every day by an instrument mechanic. No other regular maintenance is performed although the various sample pressures are checked each day to make sure that the sampling system is in order.

Operating Experience. Operation with the analyzer-controller has been very successful. This was the first infrared analyzer installed in this plant and the operators were at first doubtful of it—especially when they saw how widely the bottoms temperature varied. A few weeks of smooth operation and no loss of reflux in the other towers soon convinced everyone of its value. Ethylene recovery in the absorber increased from average values of 94 or 95 percent to values of 98 percent. Methane content of the bottoms was kept constant in the range 0.5 to 0.6 mole percent (corresponding to 9.0 to 10.0 mole percent at the analyzer sample point). The temperature at the bottom of the tower varied by as much as 30 F.

Figure 3 shows a record of analyzer results and the bottoms temperature record plotted for a period of time when one of the catalytic cracking units was starting up. The very sharp increase in temperature corresponds to a change in C_5 content from 5 mole to 20 mole percent but the analyzer controller quickly corrected for this. Any increase in methane content of the bottoms stream during this surge had no effect on the operations of the other towers.

The analyzer has now been in more or less continuous service since August 1955. Maintenance experience with it has been excellent. Daily calibration checks are excessive and in all probability these will be reduced in the near future. After start-up wanderings which are inevitable with an instrument of this kind, the analyzer ran successfully for a period of some eighteen months with little or no attention other than the daily checks. The only part which failed was the chopper motor. This failure took place after six months and had actually been forecast by the manufacturer. Steps are now taken to stock this component in spare parts so that it can be replaced as required. It seems absurd that such a simple component should fail so easily.

After 18 months, troubles began which were eventually tracked down to dirty windows in the sample cell. The cell was removed and the windows cleaned. As a probable result of this cleaning, trouble was then experienced with a leaky filter cell. This appears to have been remedied.

Most important is to avoid removing the pick-up from its thermostatted housing. Invariably, following such a removal, it takes the analyzer some days to settle down again. Indeed it is only in the period following such a removal that it is now felt daily checks are necessary.

It is difficult to give reasons for the instability which occurs after a shutdown. Possibly it is the electronics settling in again. More probably, is is due to the thermal stresses in the microphone diaphragm which take place when it is heating up and cooling down.[5]

What improvements would we make to a subsequent installation as a result of our experience with this unit? Certainly we would install double block solenoid and vent valves in the sample manifold. This is in line with the recommendations made in a recent paper on this subject.[1] Because of leaking solenoid valves, the sample cylinders are presently turned on before standardizing and then turned off again immediately after standardizing. Although this is no great hardship, it is a nuisance which can be overcome quite easily. The only other improvement which comes to mind would be the use of two sample filters in parallel with block valves in series with each filter. This would permit changing sample filters more frequently without removing the analyzer from the line and would, we feel, delay the day when the windows in the sample cell have to be cleaned.

Conclusions. The automatic nondispersive infrared analyzer is now a practical and reliable piece of apparatus. Although it is more expensive than ordinary environmental control instruments and requires more maintenance, it can be used to provide satisfactory control in systems where no other instrument is practical.

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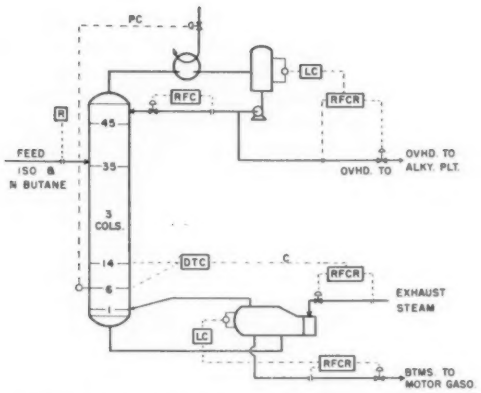

FIGURE 1—Butane splitter control by temperature difference

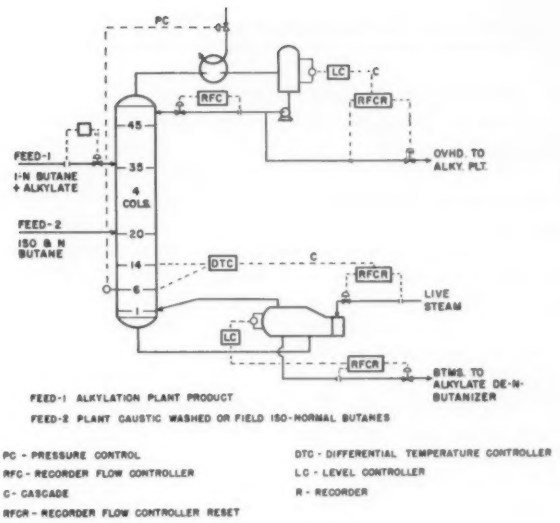

FIGURE 2—Deisobutanizer control by temperature difference

Control by Temperature Difference?

Although TDC has been successfully applied to butane splitters, it is not necessarily dependable for some isobutane separations

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THIS ARTICLE points out some limitations and some areas of applicability of temperature difference control.[1] Several years ago temperature difference control was tried on butane splitters at Humble Oil & Refining Company's Baytown refinery for the separation of normal and isobutane, in the absence of other components such as pentanes and heavier. After solving certain initial problems, this method of control proved reliable, and, in fact, resulted in the release of a plant infrared analyzer.[5] Then in early 1956, the light ends fractionation columns were rearranged in order to attain a more economic sequence of operations. After this revision, all of the butane separating operations were carried out in alkylate deisobutanizers in the presence of other components. With this operation, temperature difference control became unsatisfactory. Thus, temperature difference control is seen to have limited application.

Background. With the old operation, the alkylation plant product was completely debutanized and the overhead from these debutanizers, mainly normal and isobutane, was split (Figure 1) with the overhead isobutane being recycled to the alkylation plant and with the bottoms normal butane going to motor gasoline for vapor-pressure correction. With the new operation, the alkylation plant product is first deisobutanized (Figure 2) sending the overhead back to the alkylation plant. The bottoms is then denormalbutanized so that the overhead normal butane from this second tower goes to motor gasoline.

With both operations, it is important to separate efficiently the normal and isobutane since this separation job requires more fractionating tower capacity than any of the other separations which must also be handled in the fractionation of alkylation plant product: depropanizing, depentanizing, and alkylate rerunning. Since the control of the normal and isobutane separation with the new processing sequence was not as good with the old processing sequence, and since this separation is critical, it became important to find out why the control is hampered by

the presence of the other components and if possible, to arrive at quantitative results.

Basic Control Concepts. Before explaining why the differential temperature control would not work for the separation of normal and isobutane in the presence of large concentrations of non-key components, it will be explained why it works in the case of a binary and why it was tried in the first place. The conventional means for controlling a fractionating tower is influenced by two basic requirements; first, the capacity must be controlled, and secondly, the cut point (percentage overhead), or equivalently a terminal composition, must be controlled.

The two means of capacity control are achieved by holding either reflux or steam constant. If a fractionating column is operating in a range of liquid-to-vapor ratio where the liquid rate is controlling, it is best to put the reflux on rate-of-flow conrol and then vary the steam rate in order to get cut point control. On the other hand, if the liquid-to-vapor ratio is such that the vapor rate is the controlling factor, then the reboiler steam or the furance fuel, depending upon the type of heater used, should be put on rate-of-flow and the reflux can then be varied for cut point control. An additional restriction is usually imposed in terms of the product, overhead or bottoms, which must meet specification. If the overhead quality is critical and if the tower is limited by vapor capacity, then the heat input may be held constant and overhead composition control can be attained by automatically varying the reflux from a temperature point in the top section of the tower. However, if the liquid rate is the limiting factor in the operation of the tower, then some debit must be accepted in terms of percentage of tower capacity utilized in order to attain control. Whether liquid or vapor rates are limiting in a given situation depends, of course, upon the ratio of perforations or bubble caps to overflow downpipes.

In the following discussion, it is assumed desirable to fix the reflux on rate-of-flow control and having fixed it, vary the steam rate automatically in order to control the column to a desired bottoms quality.

The conventional type of control in this situation is from the measurement of temperature and pressure in the bottoms section of the tower. In a 50-plate fractionating tower, it would be logical to control from the fifth to tenth plate. Actually, the objective is to control to a certain bottoms composition by means of an intermediate plate composition. This is usually done inferentially, by controlling vapor pressure on an intermediate plate. The pressure gauge is installed on the same plate as the thermocouple in order to prevent interference from changes in tower pressure drop. This gives good control if the tower pressure is held constant. But if the pressure varies and if the phase rule concept, or its modifications[2] are taken into account one might consider the possible equivalence of fixing two temperatures instead of fixing a temperature and a pressure. Thus, by controlling two temperatures, or a temperature difference, the effect of pressure variations would be minor since the effect of pressure on both of the plates where the thermocouples would be located would be about the same. Actually, the assumption here of a constant slope of the vapor-pressure curve for two components on plates close together is quite good since for hydrocarbons, the slope of the vapor-pressure curves is essentially constant at a given pressure.

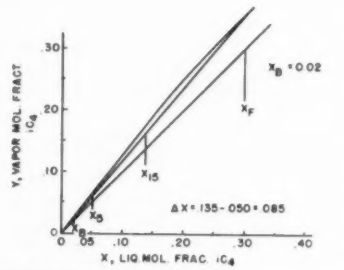
Y, VAPOR MOL FRACT iC4
X, LIQ MOL FRAC iC4
X_B = 0.02
X_F
X_{15}
X_5
ΔX = .135 - .050 = .085
BASIS: X_F = 0.30, α = 1.30
DIFFERENCE COMPOSITIONS FOR PLATES NO. 5 & 15

FIGURE 3

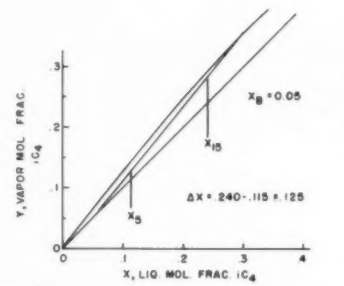
Y, VAPOR MOL FRAC iC4
X, LIQ MOL FRAC iC4
X_B = 0.05
X_{15}
X_5
ΔX = .240 - .115 = .125
BASIS: X_F = 0.30, α = 1.30
DIFFERENCE COMPOSITIONS FOR PLATES NO. 5 & 15

FIGURE 4

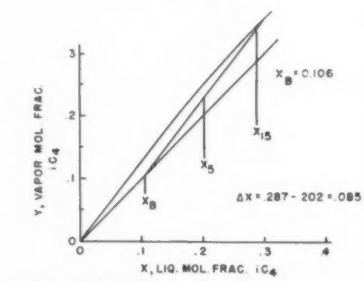
Y, VAPOR MOL FRAC iC4
X, LIQ MOL FRAC iC4
X_B = 0.106
X_{15}
X_5
X_B
ΔX = .287 - .202 = .085
BASIS: X_F = 0.30, α = 1.30
DIFFERENCE COMPOSITIONS FOR PLATE NO. 5 & 15

FIGURE 5—Estimation of bottom composition vs. plate difference composition.

It is worth pointing out that controlling two temperatures is not equivalent to controlling a temperature difference, and that failure to make this distinction was the cause of initial difficulties.

Basis for Temperature Difference Control. Now, how does temperature difference control work? Or how does temperature difference fix the cut point or percentage overhead on a fractionating column? The answer may be seen by an inspection of Figures 3 and 4. These are McCabe-Thiele diagrams[3] showing the α curve and the operating line for a butane splitter. In Figure 3, a high-purity bottoms is produced and in Figure 4, a lower-purity bottoms is produced. It is seen that Figure 3 shows a low concentration gradient across the ten plates, five to fifteen, and Figure 4 shows a higher concentration difference; these differences are labeled $\Delta X = X_{15} - X_5$. Since this concentration difference correlates with a boiling point difference and we are measuring boiling point differences with the differential temperature instrument, then the bottoms composition, or equivalently percentage overhead can be controlled by ΔT.

This brings up the first obstacle met initially in the application of differential temperature control to

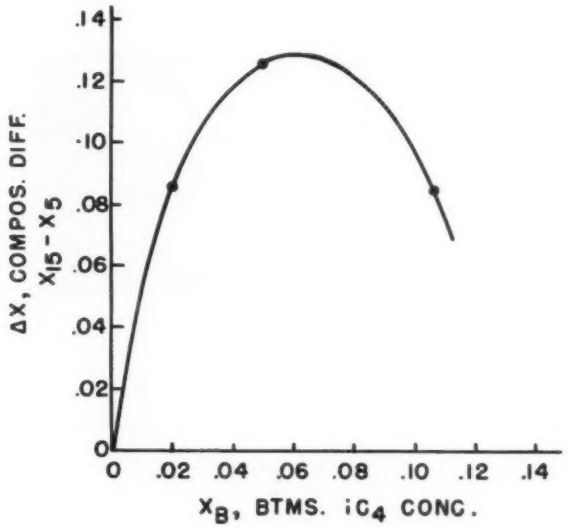

FIGURE 6 (above)—Bottoms composition vs. plate difference composition.

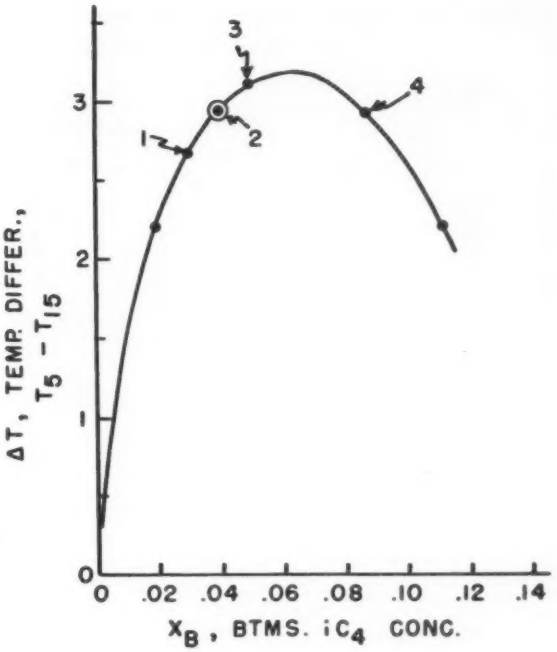

FIGURE 7 (right)—Bottoms composition vs. plate temperature difference.

butane splitters. Figure 5 shows the same alpha curve as that shown in Figure 3 and 4, but here a much higher bottoms composition is being produced. Figure 5 was calculated to produce the concentration difference obtained in Figure 3. Figure 6 plots the results from Figures 3, 4, and 5, showing the bottoms composition versus the concentration difference across Plates 5-15. The temperature difference instrument "sees" this concentration difference, the ordinate line in Figure 6. These concentration differences are converted to temperature differences by means of a boiling-point curve for this binary mixture and are plotted in Figure 7. Now if one takes the viewpoint of the differential temperature instrument, it is clear that a given temperature difference can exist at two widely different bottoms compositions. In other words, this curve is double-valued.

It is seen that this curve peaks at about 6 percent isobutane concentration in the bottoms. Normally it is economical to operate at about 4 percent isobutane in the bottoms. Point 2 in Figure 7. This means that normal operation is on the left side of the peak. In this region, when the set point on the ΔT instrument is at 4° and the actual ΔT is 5°, the way to achieve a lower ΔT is to raise the steam. In other words, in this region an increase in steam reduces the temperature difference. This action is a requirement for successful control action utilizing this information, and, therefore, the hardware in the control system is arranged in this way. Suppose the objective or set point is 4 percent and suppose

TABLE 1—Results of Computer Calculations
40 Plates, Feed No. 25, at B.P.

Case Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Feed Composition, M %																	
Propane	2.4																
I-butane	51.4																
Butylenes	0.8																
N-butane	26.0																
I-pentane	6.1			→	1.5												
N-pent.	.7			→	0												
Heavier	12.6			→	17.9												
Total	100.0																
Intensity, V/F	2.76											2.0			3.5		
Yield, F/F	0.637	0.6207	0.5979	0.5738	0.6370	0.6207	0.5970	0.5738	0.5300	0.4900	0.5400	0.600	0.550	0.500	0.600	0.550	0.500
I-butane conc., M %																	
As is: Ovhd.	80.6	82.6	85.7	89.0	80.6	82.6	85.8	89.1	*	92.6	92.0	84.9	87.5	89.0	86.2	*	*
Btms.	0.16	0.22	0.36	0.80	0.15	0.20	0.32	0.68		11.6	3.7	1.9	6.4	13.0	0.15		
On i-nC_4's: Ovhd.	84.9	87.1	90.5	94.1	84.9	87.1	90.6	94.2		98.1	97.1	89.6	92.3	94.3	91.1		
Btms.	0.34	0.45	0.70	1.47	0.32	0.41	0.62	1.26		19.1	6.5	3.7	11.5	21.7	0.29		
N-butane conc.																	
As is: Ovhd.	14.3	12.2	9.0	5.6	14.3	12.2	8.9	5.5		1.8	2.7	9.9	7.3	5.4	8.4		
On i-nC_4's: Ovhd.	15.1	12.9	9.5	5.9	15.1	12.9	9.4	5.8		1.9	2.9	10.4	7.7	5.7	8.9		
Temps.: Plate 6	141.2	141.1	140.9	140.2	141.1	141.0	140.8	140.2		132.4	136.9	139.9	136.1	133.1	140.3		
Plate 10	140.6	140.4	139.9	138.7	140.6	140.4	140.0	138.9		129.6	133.8	137.5	133.2	130.8	139.9		
Plate 16	138.6	138.1	137.1	134.8	138.7	138.3	137.3	135.2		127.8	129.9	133.3	130.5	129.4	138.2		
Plate 27	127.9	127.6	126.8	125.6	128.0	127.6	126.8	125.6		123.5	124.0	125.4	124.8	124.5	127.9		
Plate 37	124.7	124.2	123.3	122.3	124.7	124.2	123.3	122.2		121.0	121.3	123.2	122.5	122.0	123.3		
Plate 30	127.3	126.8	126.2	124.6	127.4	126.9	126.0	124.6		122.5	123.1	124.9	124.3	123.8	126.4		
Delta T: $T_6 - T_{16}$	2.6	3.0	3.8	5.4	2.4	2.7	3.5	5.0		4.6	7.0	6.6	5.6	3.7	2.1		
$T_{27} - T_{37}$	3.2	3.4	3.5	3.3	3.3	3.4	3.5	3.4		2.5	2.7	2.2	2.3	2.5	4.6		

* Did not converge.

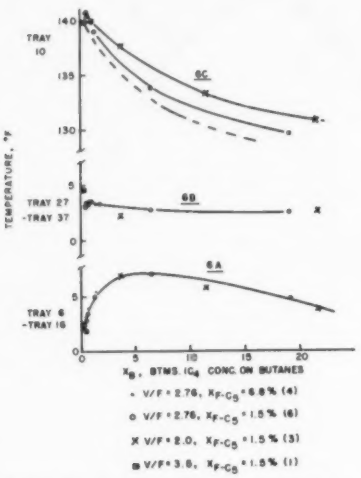
TRAY 10
TRAY 27 -TRAY 37
TRAY 6 -TRAY 16
6C
6B
6A
TEMPERATURE, °F
X_B, BTMS. IC_4 CONC. ON BUTANES
• V/F = 2.76, X_{F-C_5} = 6.8% (4)
o V/F = 2.76, X_{F-C_5} = 1.5% (6)
× V/F = 2.0, X_{F-C_5} = 1.5% (3)
▫ V/F = 3.5, X_{F-C_5} = 1.5% (1)

FIGURE 8—Calculated correlations with bottoms composition.

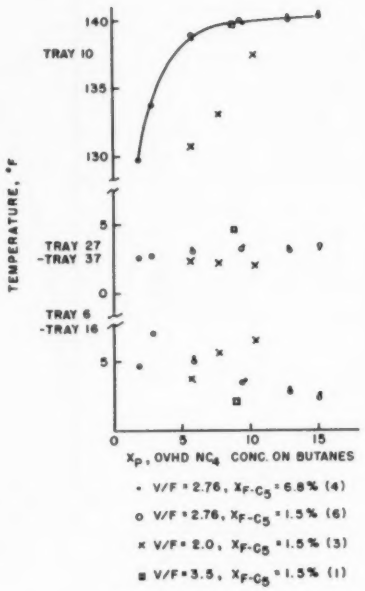
TRAY 10
TRAY 27 -TRAY 37
TRAY 6 -TRAY 16
TEMPERATURE, °F
X_D, OVHD NC_4 CONC. ON BUTANES
• V/F = 2.76, X_{F-C_5} = 6.8% (4)
o V/F = 2.76, X_{F-C_5} = 1.5% (6)
× V/F = 2.0, X_{F-C_5} = 1.5% (3)
▫ V/F = 3.5, X_{F-C_5} = 1.5% (1)

FIGURE 9 (above)—Calculated correlations with overhead composition.

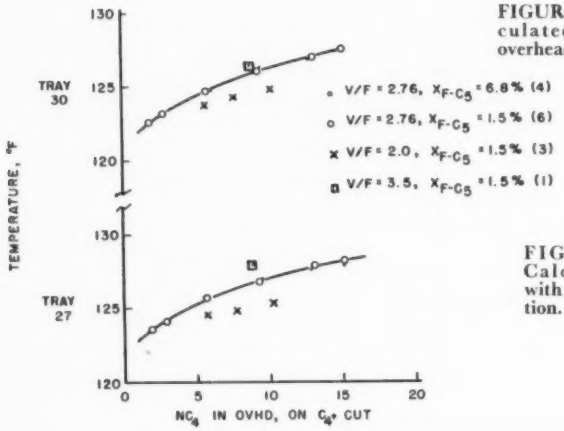

FIGURE 10 (left)—Calculated correlation with overhead composition.

About the Author

W. O. Webber is a staff engineer for Humble Oil & Refining Co., Baytown, Texas, where he designs and develops new control systems. Holder of a B.S. degree in chemical engineering from the University of Oklahoma, he has been with Humble 21 years. Work has included light ends recovery and fractionation, crude distillation, aviation gasoline manufacture, refinery coordination, lube production, economics and advanced instrumentation. Webber has also taught in Humble's Practice School for Junior Engineers.

TABLE 2—Basis for Computer Calculations

Feed Composition	Mol Fraction	Alpha At 140 F*.
Propane	0.024	3.32
Isobutane	0.514	1.34
Butylenes	0.008	1.18
N-butane	0.260	1.00
Isopentane	0.061	.43
N-pentane	0.007	.33
I-hexane	0.010	.17
I-heptane	0.005	.11
I-octane	0.032	.05
Heavier	0.079	.03
	1.000	
Pressure, psig		
Top of column	100	
Bottom of column	110	
Between	Linear interpolation with plates	
Independent Variables Studied, Range		
P/F, mole ratio	0.49 to 0.637	
V/F, mole ratio	2 to 3.5	
X_F: C_5's, mole fraction	0.068 to 0.015	
C_6's, mole fraction	0.010 to 0.063	

* Varied with temperature.

that the actual operation is at Point 1. With these conditions, it is necessary to reduce the heat input in order to allow a greater isobutane concentration in the bottoms and to raise the temperature difference measured. So far so good, but suppose referring to Figure 7, that we are at Point 4 on this curve. The temperature difference instrument, not knowing what the X_B value is, will cut the steam in order to achieve the temperature difference of Point 2, the set point. This control action prohibits any movement toward Point 2, in that it cuts the steam off. This is the only kind of runaway experienced. When the operators observe this, the column is put back on manual control until it is back in the proper range on the left hand side of the peak. Then, it is put back on automatic control.

As noted above, runaways were satisfactorily infrequent in the butane splitter operations. In fact this type of control was eminently successful. Naturally, it was desirable to try it in the butane separation carried out in the deisobutanizers. Preliminary computer calculations[4] indicated that this control scheme would work: ΔT was sensitive to bottoms isobutane composition, and the correlation was insensitive to feed composition and reflux ratio in the ranges studied. These results are shown in Figure 8. (Tabulated results are presented in Tables 1 and 2.) But actual operation was unsatisfactory. With the new revised processing sequence, runaways are so frequent, that the deisobutanizer columns stay on manual control most of the time: the control system failed to be automatic. The operators tried to make this control scheme work for several months on four different fractionating columns and although the system worked very well for periods of a few hours, consistently good operation was not obtained. Therefore, straight temperature control from the fifth plate

was tried on one of the deisobutanizer columns with improved results. Because of the good results obtained, temperature control of the deisobutanizer columns has been recommended. The change is easily justified by the attainment of more consistent overhead isobutane purities in the alkylation plant and the prevention of quality runaways in the alkylation plant when the isobutane concentration gets too low. At the other extreme, large volumes of isobutane are discarded in the bottoms of the deisobutanizers and isobutane escapes into motor gasoline blending, where it is worth less than its purchase price.

The use of other possible control points and their sensitivities are shown in Figure 9 and 10. These results typify what may be obtained from digital computer calculations for use in designing control systems for distilling multicomponent mixtures.

Now, why does temperature difference control not work when components heavier than the heavy key components are present. Several answers are possible, and some are described in the appendix. Our best answer is that the runaway as described above is more likely, because of the two feed situations and because of the unequal effect of transient heavy component concentrations at the two trays. The two feed situation permits a rapid change in feed composition, extremely unlikely for single feed towers, with the resultant unusual concentration shifts up and down the tower.

Conclusions. Differential temperature control has been successfully applied to butane splitters but it is not dependable for the same isonormal butane separation carried out in the presence of pentanes plus alkylate on a column with two feed stocks.

In conclusion, an attempt will be made to define the areas wherein temperature difference should work. First, of course, the distillation operation should meet one of the same qualifications that straight temperature control must meet: that a region must be found in the tower where cut components can be measured, free from interference from other components. The other qualifications are:

1. The ΔT instrument should be located near that terminal, top or bottom, that is relatively pure, say less than 6 percent key component impurity,
2. Non-key component should not contribute a major concentration in the same terminal, say less than 25 percent,
3. The non-key component should have a relative volatility greater than that of the keys, say 50 percent greater.
4. The variation in feed composition should be either small, less than ± 10 percent, or relatively slow, less than one cycle per day.

These qualifications can be shortened to: a binary distillation with at least one product relatively pure.

Does TDC Always Give Good Control?

Several hypotheses were tested in order to determine why temperature difference control gives poor control. Since these considerations have some theoretical interest, they are included. But since they have been shown to be unimportant, they are relegated to the appendix.

Different Short and Long Term Effects. First, it was thought that the immediate effect of an increase in steam rate might be different from the steady state or sustained effect. For example, referring to Figure 7, it will be recalled that an increase in heat input will reduce the bottoms isobutane composition and therefore the temperature difference. But it is easy to imagine that the first effect of an increase in heat input might be on the lower tray, which would increase delta T. This initial effect might call for more steam, repeat, and finally open the steam wide. Plant tests showed that this effect did indeed exist, but was very small, only about 0.1 F. or 1/10 of the steady state effect. Furthermore, much plant experience showed that runaways have never occurred in the direction of wide open steam.

Different or Unpaired Measurement Lags. Second, it was supposed that the temperature measurements might have different lags. From the above discussion, it could be bad, if the lower measurement were faster. Plant tests were made with independent checks, using two thermocouples to check against the temperature difference measurement.

Although the data were not precise, it may be said that: (1) the thermocouples had much smaller dead times than the paired resistance elements, 1 minute vs. 6 minutes, (2) the thermocouples had the same "time constant," about 40 minutes, and (3) there was essentially no indication that the lower measurement moved sooner as a result of a change in heat input.

Variation of Bottoms Concentrations-Steam Sensitivity With Feed Composition. The wide variation in feed compositions which occurred with two different feeds, gave rise to the speculation that impossible control restrictions are imposed on the system when the feed, and therefore the bottoms, becomes extremely lean in normal butane. This would occur when the lower feed is greatly reduced or cut out. By control restriction is meant the sensitivity of bottoms or fifth tray composition x, to heat input, steam valve movement, or pen movement, y. If sensitivity is defined as dx_B/dy_v and it is desired to control bottoms composition x_B to 5 percent ± 0.1 percent, then the equivalent value position y_v must be continuously attainable. Steady state calculation showed a sensitivity requirement of 0.006 inches of pen travel on a 3-inch chart in order to control bottoms isobutane concentration-on-butanes to 1 percent. It was suspected that a much greater sensitivity would be required for a normal butane-lean (with respect to pentanes and heavier) feed. However, the calculation of several cases showed that this sensitivity requirement was not altered by substituting pentanes for normal butane. The reason for the almost constant sensitivity in these cases was that with heavier present, more heat input was required to provide the sensible heat effect and the temperature increase. This general subject is discussed by Marcy and Yachter in Tustin.[6]

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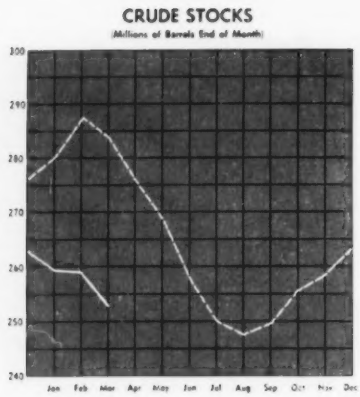

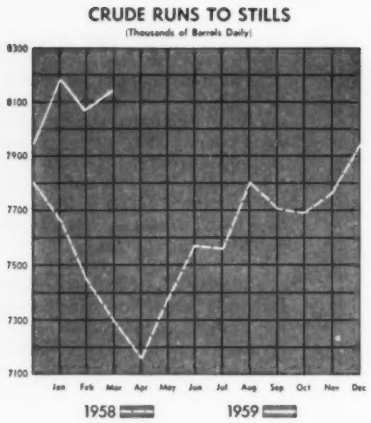

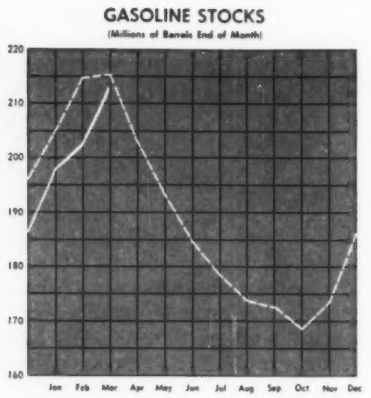

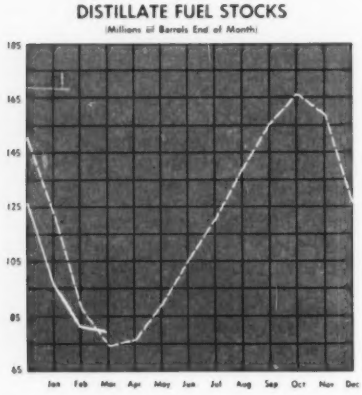

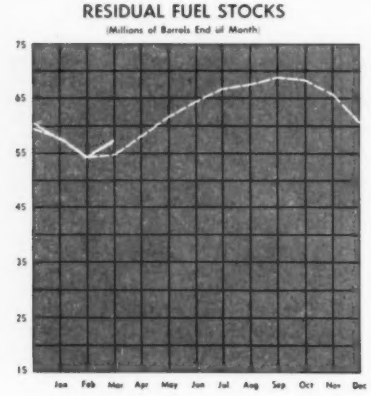

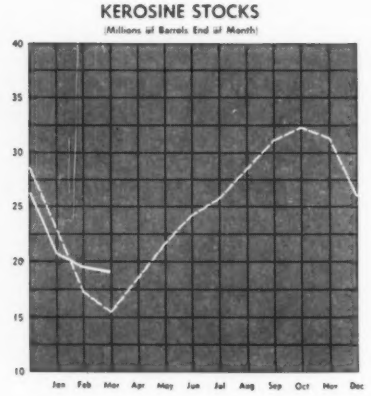

Taking Stock

- Crude stocks continue to drop
- Runs to stills up again
- Kerosine stocks leveling off

U.S. Petroleum Demand and Supply (Thous. Bbls. Daily)

ITEM	March 1959	March 1958	March % Diff.	Feb. 1959	January-March 1959	January-March 1958	January-March % Diff.
DEMAND							
All Oils, Total Demand	9,901	9,079	+ 9.1	10,664	10,636	9,960	+ 6.8
Domestic Demand	9,631	8,805	+ 9.4	10,672	10,373	9,697	+ 7.0
Export Demand	270	274	— 1.5	250	264	263	+ 0.4
Gasoline, Total Demand	3,913	3,569	+ 9.6	3,641	3,777	3,529	+ 7.0
Distillate, Total Demand	2,201	2,075	+ 6.1	2,795	2,706	2,595	+ 4.3
Kerosine, Total Demand	342	357	— 8.8	467	464	503	— 7.8
Residual, Total Demand	1,803	1,568	+15.0	2,038	1,991	1,768	+12.6
CHANGE IN STOCKS							
All Oils, Change in Stocks	+203	—379	.....	—357	—444	—820	.....
NEW SUPPLY							
Total New Supply	10,104	8,700	+16.1	10,307	10,193	9,140	+11.5
Domestic Production, Total	8,023	7,069	+13.5	8,034	8,048	7,451	+ 8.0
Crude Oil	7,173	6,273	+14.3	7,194	7,197	6,644	+ 8.3
Natural Gas Liquids	850	796	+ 6.8	840	851	807	+ 5.5
Imports, Total	2,081	1,630	+27.7	2,273	2,145	1,719	+24.8
Refined Products	1,193	619	+92.7	1,273	1,210	730	+65.8
Crude Oil, Total	888	1,012	—12.3	1,000	935	959	— 2.5
Crude, East Coast	696	860	—19.1	748	738	803	— 8.1
CRUDE RUNS							
Crude Runs to Stills	8,149	7,356	+10.8	8,079	8,155	7,517	+ 8.5
Domestic Crude	7,209	6,435	+12.0	7,337	7,264	6,589	+10.2
Foreign Crude	940	921	+ 2.1	742	898	928	— 3.2

U.S. Stocks of Oils (Million Bbls. at End of Month)

KIND OF OIL	TOTAL IN U.S Mar. 1959	TOTAL IN U.S Mar. 1958	TOTAL IN U.S % Diff.	TOTAL IN U.S Feb. 1959	EAST OF CALIFORNIA Mar. 1959	EAST OF CALIFORNIA Mar. 1958	EAST OF CALIFORNIA % Diff.	EAST OF CALIFORNIA Feb. 1959
All Oils	752.8	767.5	— 1.9	746.5	.....	.....	.....	.....
Crude Oil	253.5	278.5	— 9.0	259.1	214.0	234.8	— 8.9	219.3
Gasoline	213.3	218.7	— 2.5	207.5	184.0	189.7	— 3.0	178.8
Distillate Fuel Oil	78.1	75.3	+ 3.7	81.3	64.9	62.8	+ 3.3	70.6
Kerosine	18.4	16.7	+10.2	19.4	18.2	16.3	+11.7	19.0
Residual Fuel Oil	57.9	54.9	+ 5.5	54.7	30.0	25.6	+17.2	26.2

Sources: Except for latest two months, all data in above two tables are from U.S. Bureau of Mines. Last two months are based on American Petroleum Institute weekly reports, Bureau of Mines weekly crude stock reports, and Petroleum Refiner estimates.

Heat Transfer Nomographs

Part 7—Heat transfer coefficients for liquids and gases inside tubes

PART 8—Heat transfer coefficients for liquids and gases outside tubes

Part 9—Water film coefficients for normal and annular flow

Jose Alvarez C., Lubrisol de Mexico, S. De R. L.
Carlos Duhne, Instituto de Investigaciones Industriales, Monterrey, Mexico

HEAT TRANSFER calculations for fluids flowing through banks of tubes are usually difficult. Here are two nomographs which quickly solve these problems.

Heat transfer coefficients for fluids outside tubes. McAdams[14] and Shack[18] recommend the following equation:

$$\frac{h D_o}{k_f} = 0.33 \left(\frac{C_p \mu_f}{k_f}\right)^{1/3} \left(\frac{D_o G_{max}}{\mu_f}\right)^{0.6}$$

Where: Nu, Nusselt number, $\frac{h D_o}{k_f}$

Pr, Prandtl number
Re, Reynolds number
D_o, External diameter, ft.
k_f, Thermal conductivity at film temperature Btu/hr. ft. °F.
G_{max}, Mass velocity based in minimum cross section
t_f, Film temperature, equal to mean bulk and wall temperature

This equation is used for Reynolds numbers between 2,000 and 40,000. Nomograph No. 17 was constructed to solve this equation.

This equation is valid only when the number of rows of tubes is larger than 10. For staggered tubes less than 10 rows and for tubes is line, a correction factor given by the following table[14] should be included.

Example: Find the value of Nu_o for a fluid with a Prandtl number of 1.0, flowing through a bank of tubes of 10 rows, with a Reynolds number (Re_{max}) of 6,000.

Solution: Using Nomograph No. 17 Nu equals 62.

Fluids outside tubes, gases flowing through a bank of tubes—McAdams[14] recommends the following simplified equation for gases flowing normal to staggered banks of tubes.

$$h = 0.133\, C_p\, G_{max}^{0.6}/D^{0.4}$$

Ratio of hm for N rows deep to that for 10 rows deep.

N	1	2	3	4	5	6	7	8	9	10
Ratio for staggered tubes	....	0.73	0.82	0.88	0.91	0.94	0.96	0.98	0.99	1.0
Ratio for in-line tubes	0.64	0.80	0.87	0.90	0.92	0.94	0.96	0.98	0.99	1.0

Where: h, Film coefficient, Btu/hr. sq. ft. F.
C_p, Specific heat, Btu/lb. F.
G_{max}, Mass velocity based on minimum cross section
D, External diameter, feet

Example: 6,000 lb./hr. of air at 60 F. are to be heated to 180 F. flowing at 8 ft./sec. through a staggered bank of tubes. Inside the tubes steam condenses at 250 F. Tubes are 1.6 feet long, and 1 inch external diameter. The cross section of the apparatus is 2.6 sq. ft. C_p=0.24 Btu/lb. F.

Find the value of the film coefficient.

Solution: The minimum cross section is $2.6 - \frac{1.6 \times 1 \times 9}{12} = 1.4$ sq. ft.

$$G_{max} = \frac{w}{A} = \frac{6,000}{1.4} = 4,300 \text{ lb.hr. sq. ft.}$$

Using Nomograph No. 18, h is found to be 13.1 Btu/hr. sq. ft. F.

Key : G_{max} — C_p : L
L — D : h

LITERATURE CITED

[14] McAdams, W. H., Heat Transmission, McGraw Hill Book Co., Inc., 1942.
[18] Shack, A., Industrial Heat Transfer, John Wiley & Sons, Inc., 1943.

TO BE CONTINUED

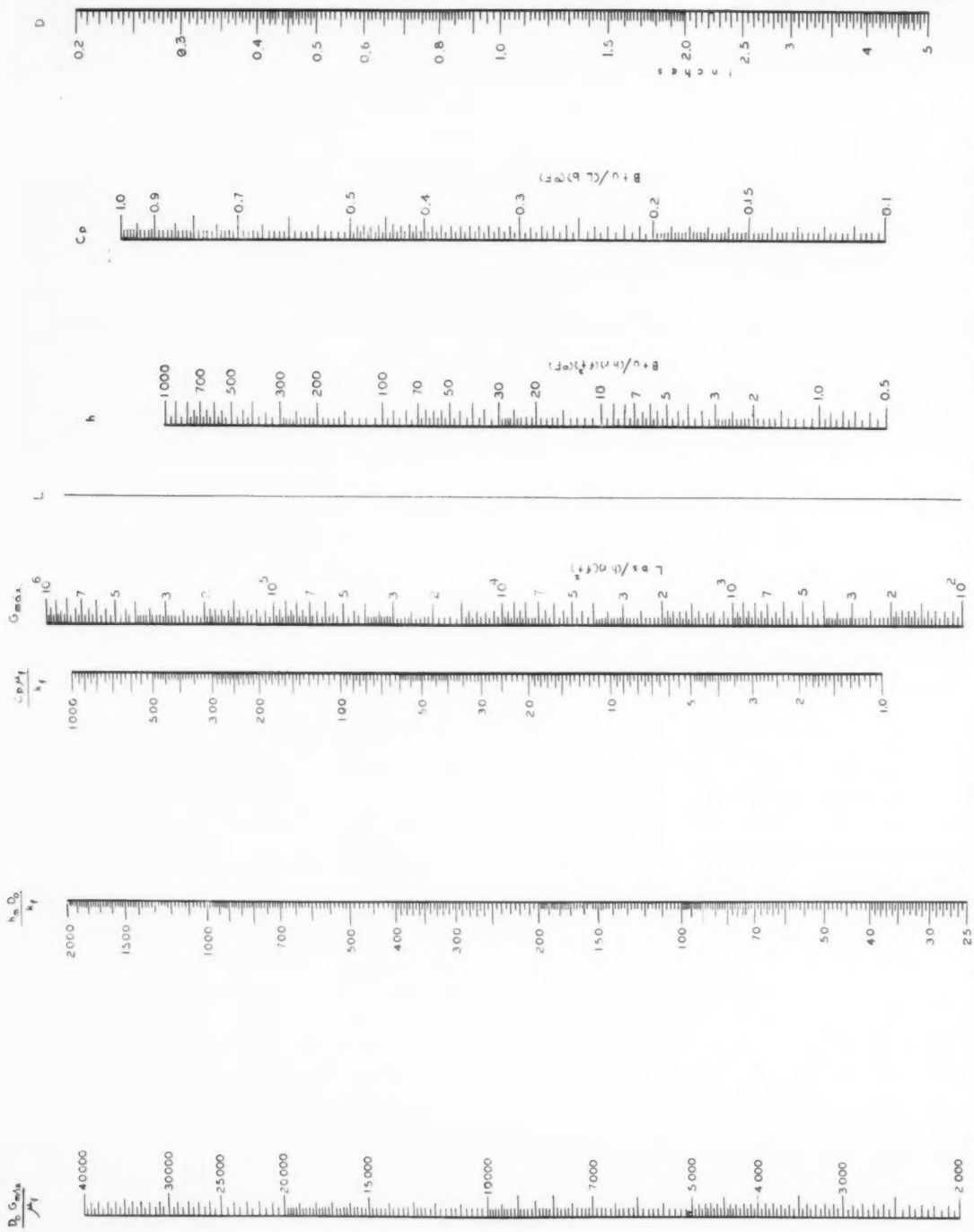

FIGURE 18—Heat transfer coefficients for gases flowing through a bank of tubes.

FIGURE 17—Heat transfer coefficients for fluids outside tubes.

Applied Hydrocarbon Thermodynamics

Part 10B: Charts for Making Compressor Calculations

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Irreversible Compression. For an irreversible path, the first law relationship in Equation 8.1 becomes

$$\Delta H = Q + \int VdP + T_{av}\,\Delta S_{Production} \qquad (10.1)$$

The term ($\Delta S_{Production}$) is the entropy generated by the irreversibility, i.e., friction and turbulence, in the gas during compression. This designation is necessary because $Q = T\,\Delta S$ for a reversble nonadiabatic process.

Irreversibility is most frequently expressed as an efficiency or ratio. Such a reversible efficiency is defined for an adiabatic process, as

$$e_r = \frac{(-W_s)_{rev}}{(-W_s)_{irrev}} = \left[\frac{\int VdP}{\int VdP + T_{av}\,\Delta S_{Prod}}\right] \qquad (10.2)$$

An adiabatic efficiency was previously defined for reversible polytropic paths as

$$e_a = \frac{\Delta H}{\int VdP} = \frac{\int VdP + Q}{\int VdP} \qquad (8.2)$$

The product of the "adiabatic" and "reversible" efficiencies is defined as the compression efficiency, e_c.

$$e_c = (e_a)\,(e_r) = \left[\frac{\Delta H}{\int VdP}\right]\left[\frac{\int VdP}{\int Vdp + T_{av}\,\Delta S_{Prod}}\right] \qquad (10.3)$$

$$e_c = \left[\frac{\Delta H}{\int VdP + T_{av}\,\Delta S_{Prod}}\right] = \left[\frac{\int VdP + Q}{\int VdP + T_{av}\,\Delta S_{Prod}}\right]$$

All the terms of this ratio are gas affects quantities. Mechanical losses are not included in Equation 10.3. All terms apply to the fluid and include reversible work, heat added and irreversibility, or entropy production terms. Bearing friction and other mechanical losses are covered by a mechanical efficiency, which is defined

$$e_m = \left[\frac{\int Vdp + T_{av}\,\Delta S_{Prod}}{\text{Shaft input work}}\right] \qquad (10.4)$$

The over-all efficiency of a compressor is defined as the product of the "adiabatic," the "reversible," and the "mechanical" efficiencies. Combining these terms gives $e_o = e_a e_r e_m$ or

$$e_o = \left[\frac{\Delta H}{\text{Shaft input work}}\right] = \left[\frac{\int VdP + Q}{\text{Shaft input work}}\right] \qquad (10.5)$$

From a knowledge of e_a, e_r, and e_m and the value of ΔH, the shaft input work is readily computed.

The values of e_a, e_r, and e_m will be established by known characteristics of the compression. It is of interest to find the corresponding temperature change exponent.

Q will be eliminated between Equations 8.2 and 10.3. From Equation 8.2

$$Q = (e_a - 1)\int VdP \qquad (10.6)$$

From Equation 10.3

$$T_{av}\,\Delta S_{Prod} = \frac{Q}{e_c} + \left(\frac{1}{e_c} - 1\right)\int VdP \qquad (10.7)$$

Combining Equations 10.6 and 10.7 with the definition $e_c = e_a e_r$ gives

$$T_{av}\,\Delta S_{Prod} = \left(\frac{1}{e_r} - 1\right)\int VdP \qquad (10.8)$$

The $\int VdP$ term may be approximated by $(RTZ)_{av} \ln \frac{P_2}{P_1}$, which is sufficiently close for this purpose, giving

$$T_{av}\,\Delta_{Prod} = \left(\frac{1}{e_r} - 1\right)(RZT)_{av} \ln \frac{P_2}{P_1} \qquad (10.9)$$

This relation will be used in deriving an expression for the temperature change exponent.

Temperature Exponent. For temperature change calculations, it is convenient to have a factor or chart that corrects the exponent n′ for irreversibility. Such a correction can be derived from the entropy balance, Equation 9.1.

$$C^{\circ}_{Pmean} \ln \frac{T_2}{T_1} = R \ln \frac{P_2}{P_1} - \Delta(\Delta S') + \Delta S \qquad (9.1)$$

Where:

ΔS = total change in entropy for the process

$$\Delta S = \frac{Q}{T} + \Delta S_{Prod}$$

By previous definitions

$$\frac{k}{k-1} = \frac{Cp^{\circ}}{R}$$

and

$$\frac{n'}{n'-1} = \frac{\ln (P_2/P_1)}{\ln (T_2/T_1)}$$

Combining these k and n′ relationships with Equation 9.1 and rearranging gives the following:

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$$\left(\frac{n'}{n'-1}\right)_{IQ} - \left(\frac{k}{k-1}\right) = \left(\frac{\Delta(\Delta S')}{R \ln \frac{T_2}{T_1}}\right) - \left(\frac{\Delta S}{R \ln \frac{T_2}{T_1}}\right) \quad (10.10)$$

For reversible and adiabatic compressions, where $\Delta S = 0$

$$\left(\frac{n'}{n'-1}\right)_{RA} - \left(\frac{k}{k-1}\right) = \left(\frac{\Delta(\Delta S')}{R \ln \frac{T_2}{T_1}}\right) \quad (10.11)$$

(Subscripts IQ and RA are defined in Table 10.3) Subtracting Equation 10.10 from Equation 10.11 and multiplying the numerator and denominator of the right side by the average temperature give

$$\left(\frac{n'}{n'-1}\right)_{RA} - \left(\frac{n'}{n'-1}\right)_{IQ} = \left(\frac{T_{av} \Delta S}{RT_{av} \ln \frac{T_2}{T_1}}\right) = \left(\frac{Q + T_{av} \Delta S_{Prod}}{RT_{av} \ln \frac{T_2}{T_1}}\right) \quad (10.12)$$

(Subscripts IQ and RA are defined in Table 10.3) This is a general equation relating the temperature change exponent for isentropic and polytropic paths; the latter may be due to heat flow or to irreversibility.

From Equation 10.12 an expression will be derived relating the temperature change exponents for the reversible and irreversible paths, both with the same amount of heat flow, if any.

Table 10.3 Four Paths

Designation	Considered Path	Heat	Entropy
RA	Reversible and Adiabatic	$Q = 0$	$\Delta S_{Prod} = 0$
RQ	Reversible and Nonadiabatic	$Q \pm 0$	$\Delta S_{Prod} = 0$
IA	Irreversible and Adiabatic	$Q = 0$	$\Delta S_{Prod} \pm 0$
IQ	Irreversible and Nonadiabatic	$Q \pm 0$	$\Delta S_{Prod} \pm 0$

Only the irreversibility effect is of interest at this point. The heat effect may be factored out by rewriting Equation 10.12 for the reversible and nonadiabatic case and subtracting this from Equation 10.12.

$$\left(\frac{n'}{n'-1}\right)_{RA} - \left(\frac{n'}{n'-1}\right)_{RQ} = \frac{Q}{RT_{av} \ln \frac{T_2}{T_1}} \quad (10.13)$$

Subtracting Equation 10.13 from Equation 10.12 gives

$$\left(\frac{n'}{n'-1}\right)_{RQ} = \left(\frac{n'}{n'-1}\right)_{IQ} = \frac{T_{av} \Delta S_{Prod}}{RT_{av} \ln \frac{T_2}{T_1}} \quad (10.14)$$

Equation 10.14 gives a relationship between the temperature change exponents for the reversible and irreversible nonadiabatic paths. For the irreversible adiabatic path, Equation 10.12 becomes:

$$\left(\frac{n'}{n'-1}\right)_{RA} - \left(\frac{n'}{n'-1}\right)_{IA} = \frac{T_{av} \Delta S_{Prod}}{RT_{av} \ln \frac{T_2}{T_1}} \quad (10.15)$$

The right sides of Equations 10.14 and 10.15 are identical. The left sides are the differences between the reversible and the irreversible exponents for the comparable paths, i.e., nonadiabatic in Equation 10.14 and adiabatic in Equation 10.15. Thus, the irreversibility correction is the same regardless of the adiabatic nature of the paths.

Combining Equation 10.9 with 10.14 or 10.15 and dropping the heat designation gives

$$\left(\frac{n'}{n'-1}\right)_{rev} - \left(\frac{n'}{n'-1}\right)_{irrev} = \frac{RZ_{av} T_{av} (1/e_r - 1) \ln \frac{P_2}{P_1}}{RT_{av} \ln \frac{T_2}{T_1}} \quad (10.16)$$

Replacing the ratio $[\ln(P_2/P_1)] / [\ln T_2/T_1)]$ by its equivalent $[n'/(n'-1)]_{irrev}$, canceling the RT_{av} terms, inverting, and rearranging gives

$$\left(\frac{n'-1}{n'}\right)_{irrev} = \left[1 + Z_{av}\left(\frac{1.0}{e_r} - 1\right)\right] \left[\frac{n'-1}{n'}\right]_{rev} \quad (10.17)$$

For convenience, Figure 10.11 has been prepared from Equation 10.17. An average compressibility factor should be used with the compressor efficiency (fraction or percentage) to obtain the efficiency factor for applying Figure 10.11. The term $\left[1 + Z_{av}\left(\frac{1.0}{e_r} - 1\right)\right]$ is called the "efficiency factor."

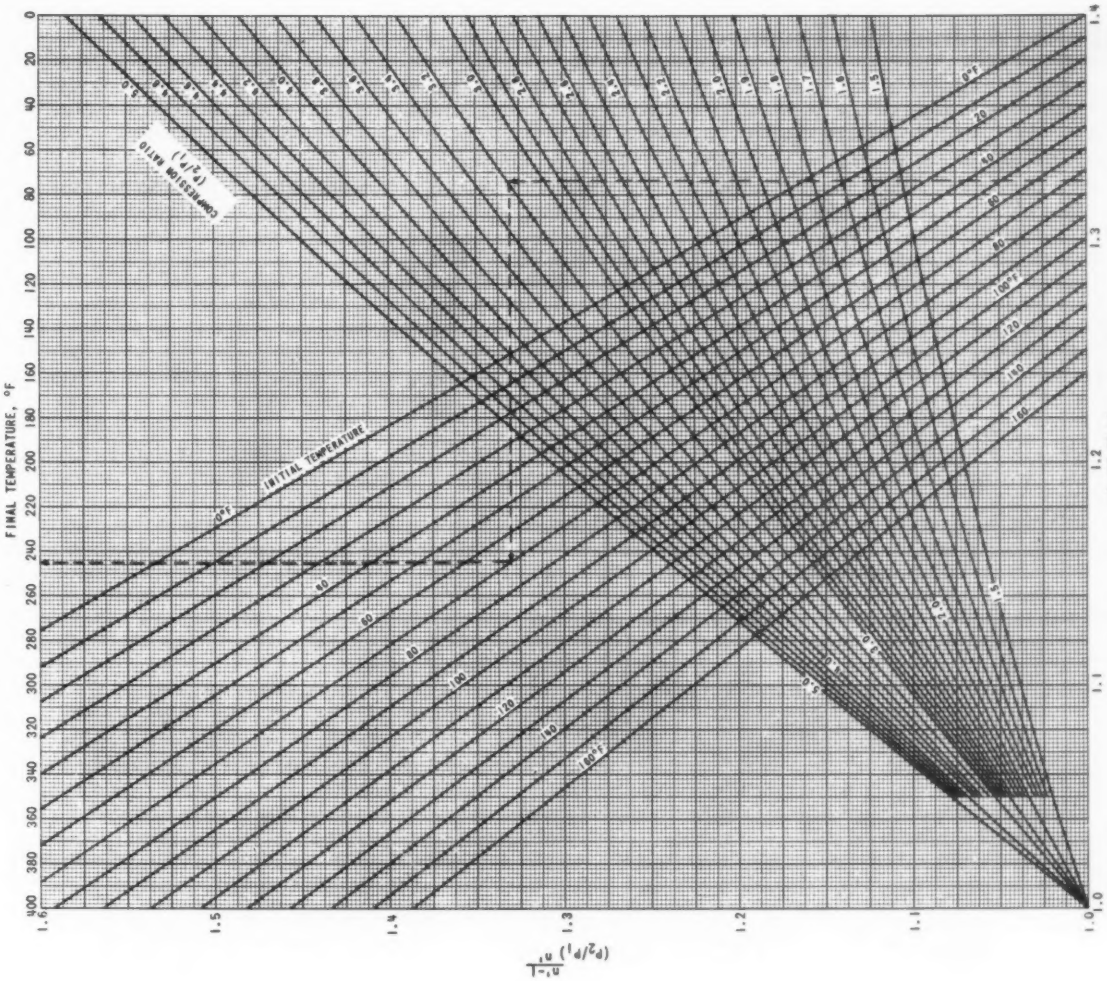
The following values of part of this efficiency factor is called illustrate its order of magnitude:

e_r	$\left[\frac{1.0}{e_r} - 1\right]$
0.95	0.053
0.90	0.111
0.85	0.176
0.80	0.250
0.75	0.333

Referring to Figure 10.11, it will be noted that the "efficiency factor" parameter fans out. In other words, irreversibility has a greater effect at high valeus of n′ than it does at low values. Stated differently, the effect of irreversibility is greater for the lighter gases, having high n′ values, than it is for the heavier gases, having lower n′ values. This relative effect will usually be exaggerated further by the "efficiency factor" being higher at the same value of e_r for lighter gases. This is due to the higher compressibility factor for light gases.

Irreversible Expansion. Nonadiabatic and irreversible conditions have the opposite effects in gas expansion than in compression, as shown below:

Operation	Condition	Efficiency	WORK	
			Sign	Relative
Compression	Heat Addition	$e_a > 1.0$	Plus	$< \Delta H$
Expansion	Heat Addition	$e_a < 1.0$	Negative	$< \Delta H$
Compression	Heat Removal	$e_a < 1.0$	Plus	$> \Delta H$
Expansion	Heat Removal	$e_a > 1.0$	Negative	$> \Delta H$
Compression	Irreversibility	$e_r < 1.0$	Plus	$> \int VdP$
Expansion	Irreversibility	$e_r > 1.0$	Negative	$> \int VdP$



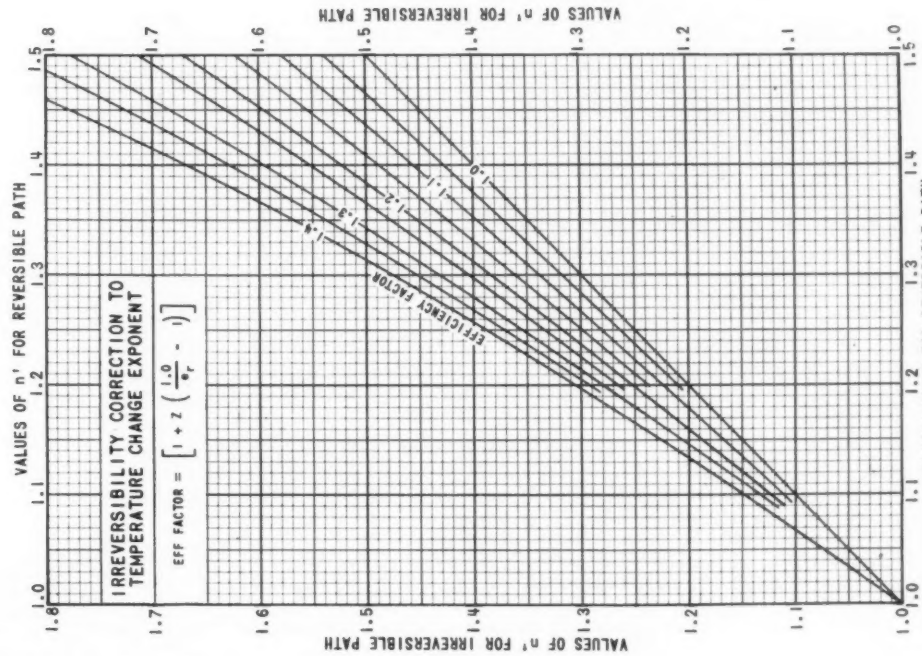

IRREVERSIBILITY CORRECTION TO TEMPERATURE CHANGE EXPONENT
EFF FACTOR = $\left[1 + Z\left(\frac{1.0}{e_r} - 1\right)\right]$
EFFICIENCY FACTOR
VALUES OF n' FOR REVERSIBLE PATH
VALUES OF n' FOR IRREVERSIBLE PATH

FIGURE 10.11—(above) Irreversibility correction to temperature change exponent.

FIGURE 10.12—(at right) Calculation chart for final temperature from exponent, n', compression ratio and initial temperature.

The enthalpy change ΔH, and the work terms, $\int VdP$ and $(-W_s)$, have a positive sign in compression and a negative sign in expansion, due to the consistent notation that has been adopted in thermodynamics. The "greater than" and "less than" signs designate relative magnitudes in the absolute values.

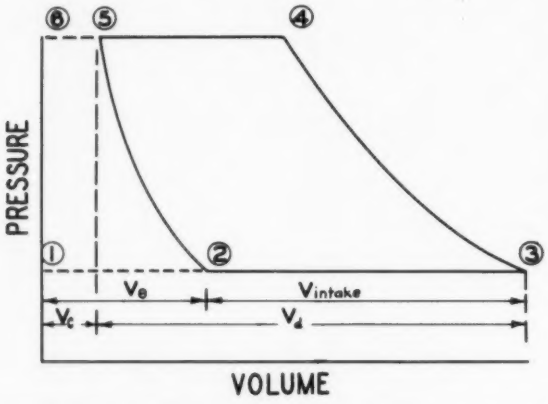


FIGURE 10.13—Diagram of reciprocating compressor cycle.

The adiabatic efficiency may be less or greater than unity, while the reversibility efficiency is always less than unty.

The same equations and charts can be used for compression and expansion calculations. Calculation charts have been developed for temperature rise, volumetric efficiency, and theoretical work. These are given as Figures 10.12, 10.14, and 10.15. Figure 10.14 is intended for reciprocating compressors.

Temperature Rise. Figure 10.12 is a two parameter chart for solving the equation

$$t_2 = (t_1 + 460)\left(\frac{P_2}{P_1}\right)^{\frac{n'-1}{n'}} - 460 \qquad (10.18)$$

for the final temperature during compression. A similar chart could be made for temperature drop during gas expansion. Figure 10.12 can be used to find the tem-

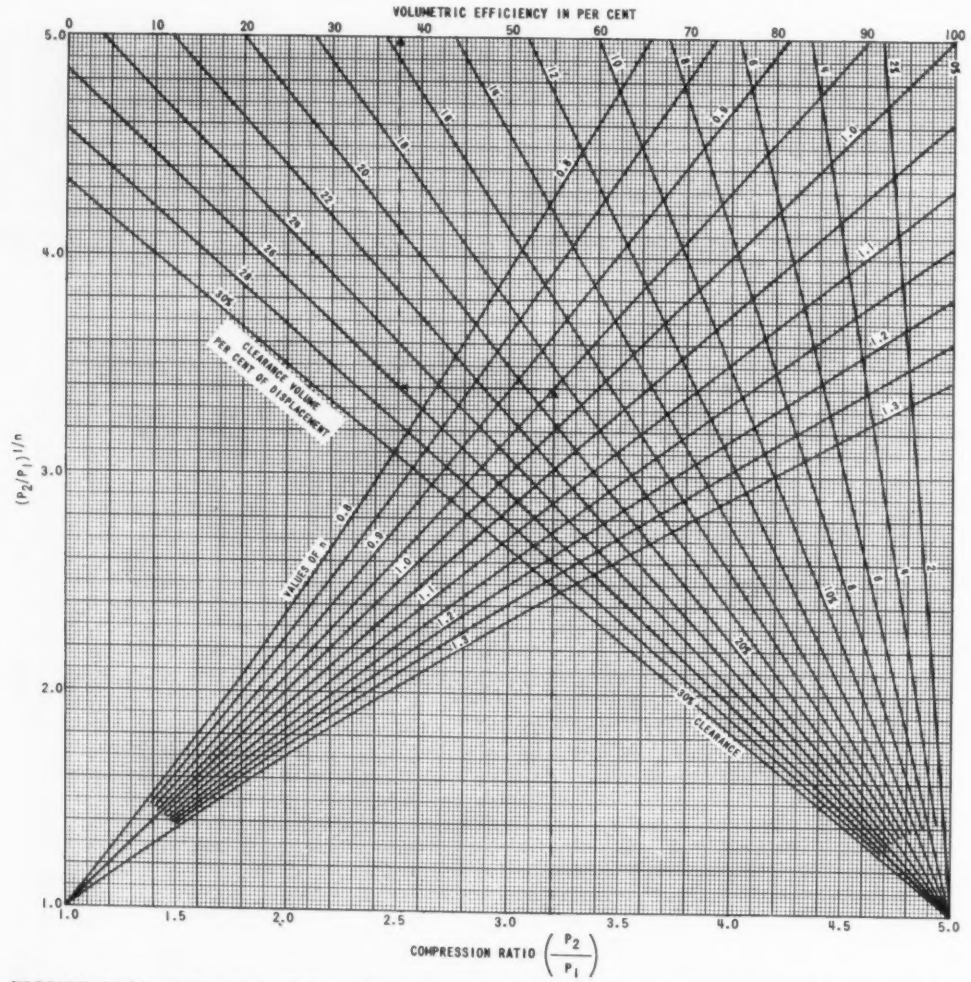


FIGURE 10.14—Volumetric efficiency for reciprocating compressors from compression ratio exponent n, and percent clearance volume.

perature rise for gas expansion by reversing the terminal temperatures and pressures.

Figure 10.12 is a composite of two charts with a common scale, i.e., (1) $(P_2/P_1)^{\frac{n'-1}{n'}}$ versus n′ for lines of constant P_2/P_1 and (2) t_2 versus $(P_2/P_1)^{\frac{n'-1}{n'}}$ for lines of constant t_1. The intermediate scale $(P_2/P_1)^{\frac{n'-1}{n'}}$ could have been omitted.

Volumetric Efficiency. Reciprocating compressors have clearance spaces between the pistons and the cylinder heads. This clearance volume remains full of high pressure gases at the end of the compression stroke. These clearance volume gases expand on the intake stroke and occupy some of the cylinder volume, thus reducing the quantity of gas that can be taken in on suction stroke.

This compressor capacity reduction may be expressed

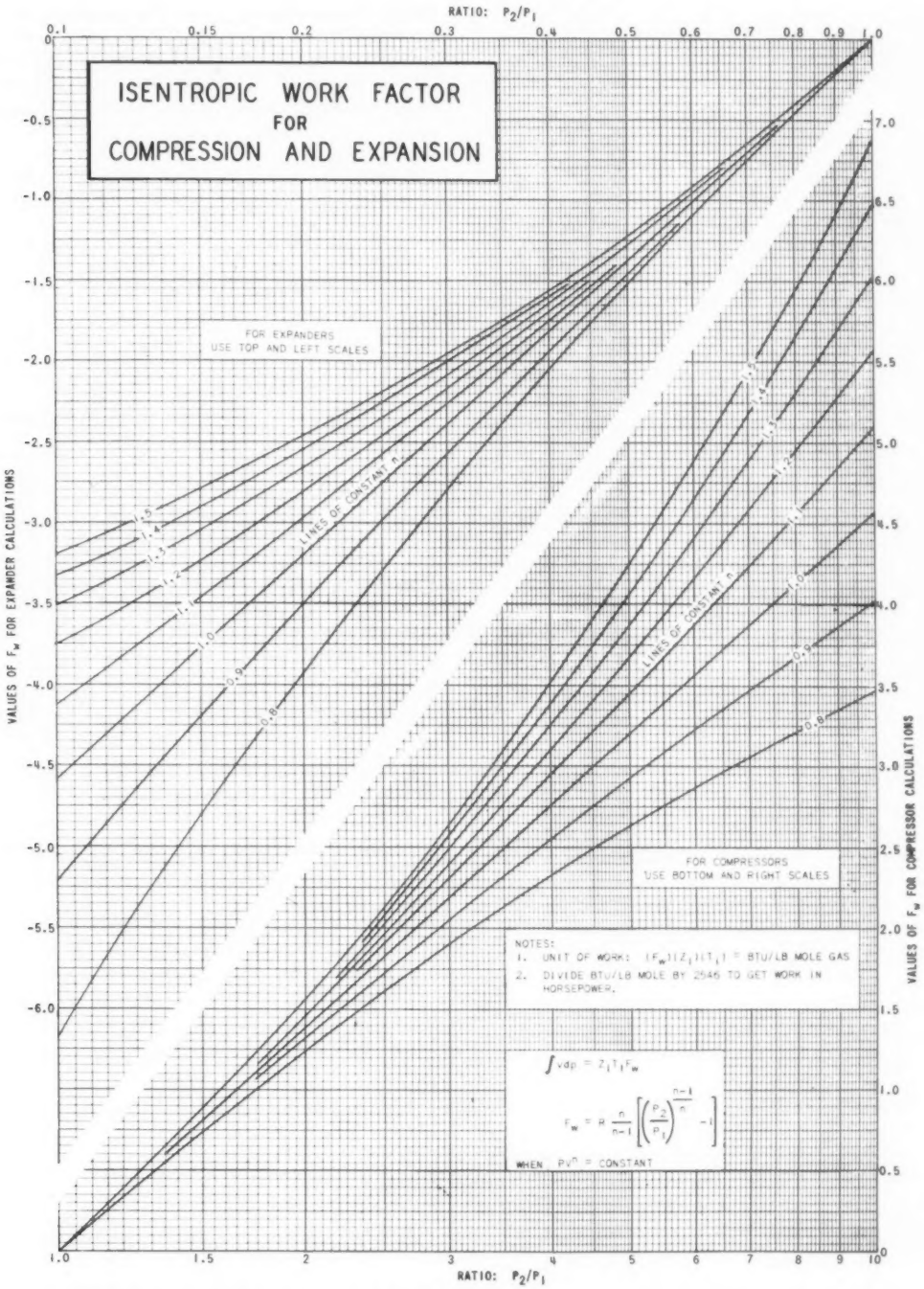

ISENTROPIC WORK FACTOR
FOR
COMPRESSION AND EXPANSION
RATIO: P2/P1
VALUES OF Fw FOR EXPANDER CALCULATIONS
VALUES OF Fw FOR COMPRESSOR CALCULATIONS
FOR EXPANDERS
USE TOP AND LEFT SCALES
FOR COMPRESSORS
USE BOTTOM AND RIGHT SCALES
LINES OF CONSTANT n
LINES OF CONSTANT n
NOTES:
1. UNIT OF WORK: (Fw)(Z1)(T1) = BTU/LB MOLE GAS
2. DIVIDE BTU/LB MOLE BY 2546 TO GET WORK IN HORSEPOWER.
∫vdp = Z1T1Fw
Fw = R n/(n-1) [(P2/P1)^((n-1)/n) - 1]
WHEN PV^n = CONSTANT

FIGURE 10.15—Isentropic factor for calculating theoretical work of compression and expansion.

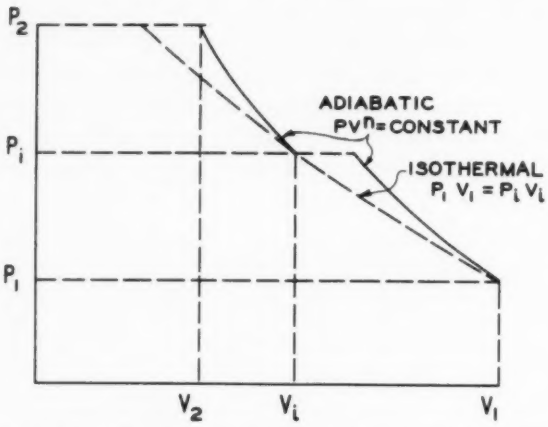


FIGURE 10.16—Diagram showing PV path for two-stage compression with intercooling.

in terms of the ratio of the gas intake to the displacement, which ratio is called the "volumetric efficiency." An equation for the volumetric efficiency in terms of the clearance volume, the compression ratio, and the pressure-volume relationship exponent, n, is derived below. For the development of this relationship, the following terms are defined:

V_d = displacement volume
V_c = clearance volume
V_e = volume to which clearance gases expand
$C = V_c/V_d$ = ratio of clearance to displacement volumes
$V_{net} = V_d + V_c - V_e$ = net volume of intake gases

The complete compression cycle is shown on Figure 10.13 where the numbers 1 through 6 designate the points of change. Eight parts of the cycle are discribed as follows:

POINT		
Without Clearance	With Clearance	Operation
3	3	Intake valve closes
3-4	3-4	Compression stroke
4	4	Outlet valve opens
4-6	4-5	Discharge stroke
6	5	Outlet valve closes
6-1	5-2	Re-expansion stroke
1	2	Inlet valve opens
1-3	2-3	Intake stroke

In practice, reciprocating compressors must have some clearance volume so the "without clearance" case is of theoretical interest only.

From Equation 7.6

$$V_e = V_c \left(\frac{P_2}{P_1}\right)^{1/n}$$

Combining the above relationships gives the following equation for the net capacity,

$$V_{net} = V_d \left[1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}\right] \qquad (10.19)$$

from which the volumetric efficiency (ratio of net intake gas per unit of time to piston displacement in same time interval) is found, as follows:

$$e_v = \frac{V_{net}}{V_d} = \left[1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}\right] \qquad (10.20)$$

Figure 10.14 is a graphical solution of Equation 10.20 giving the volumetric efficiency as a function of compression ratio, percent clearance volume, and value of the exponent, n.

Work Calculations. A previous equation, i.e., No. 8.17, gave the theoretical work $\int VdP$ as a function of the compression ratio, the exponent n, and the initial conditions. Equation 8.17 is valid as long as PV^n = constant defines the path, regardless of the numerical value of n.

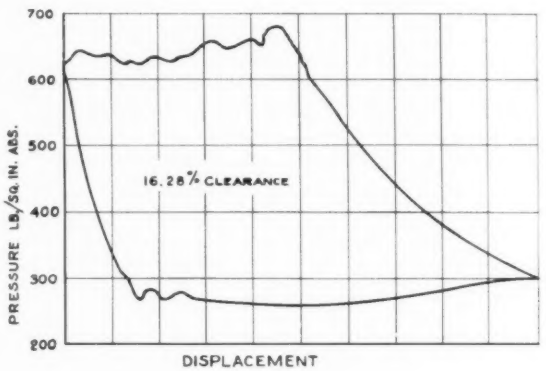
Figure 10.15 is a graphical solution of this equation for compression and expansion, as shown on the chart,

$$\int VdP = Z_1 T_1 F_w \qquad (10.21)$$

$$F_w = R \frac{n}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] \qquad (10.22)$$

where: Z_1 = compressibility factor of gas at inlet conditions
T_1 = inlet temperature °R
R = gas constant.

The work factor F_w is given as a function of com-



INDICATOR DIAGRAMS FOR HEAD END OF COMPRESSOR CYLINDER
ABOVE: CLEARANCE POCKET CLOSED
BELOW: CLEARANCE POCKET OPEN

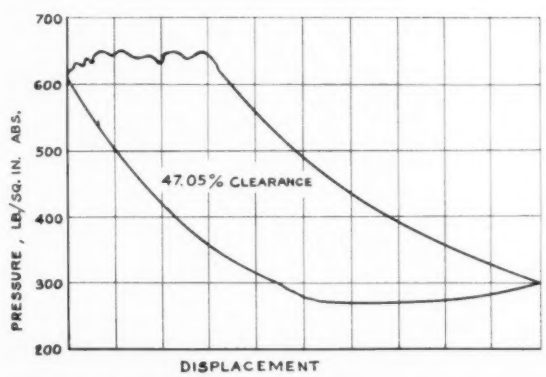
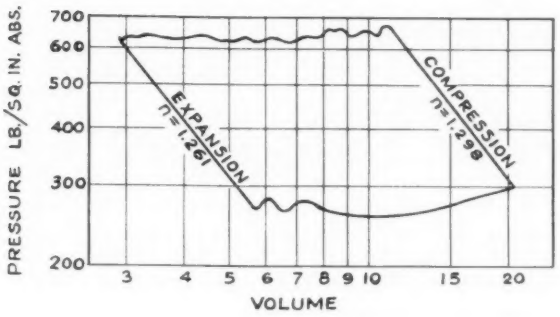


FIGURE 10.17—Typical indicator diagrams from reciprocating compressor.



LOG-LOG PLOTS OF COMPRESSOR INDICATOR DIAGRAMS

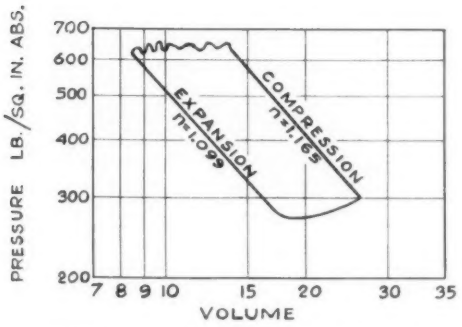


FIGURE 10.18—Log-log plot of compressor indicator diagrams.

pression ratio and exponent. Separate plots are included for compression and expansion. The units of the work found in this way are Btu/lb mole of gas. Division by 2,546 converts to horsepower.

The work found from Figure 10.15, as described above, will be the "theoretical" or "indicator" work.

Shaft input work is obtained by adding Q and dividing this theoretical work by the over-all efficiency defined previously in Equation 10.15.

An irreversible value of n, the volume change exponent, is not used in calculating the actual shaft work for compressors. It is more practical to find the theoretical or indicator work and correct this for inefficiencies or deviations.

Multistage Compression. Two or more stages, with intercooling between stages, are often used in gas compression because of the lower volumetric efficiency at high compression ratios. There is a value of P_2/P_1 for each clearance volume percentage and gas exponent, at which the re-expansion gases fill the cylinder exclude taking in any new gases.

This ratio may be found from Equation 10.20 by making

$$e_v = 0, \text{ giving } \frac{P_2}{P_1} = \left(\frac{1+C}{C}\right)^n \qquad (10.23)$$

For 10 percent clearance volume, the P_2/P_1 ratio at no capacity is found to be 28.6 at n = 1.4; 17.7 at n = 1.2; and 11 at n = 1.0.

The intermediate pressure for two-stage compression may be chosen so that the total work is a minimum or it may be selected to minimize the machine cost. The minimum work criteria can be expressed mathematically when the interstage cooling takes the gases back to the inlet gas temperature. This is the case illustrated on Figure 10.16.

Total work for the two stages is

$$(-W_g)_{\text{total}} = (-W_g)_1 + (-W_g)_2 =$$

$$\frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_i}{P_1}\right)^{\frac{n-1}{n}} + \left(\frac{P_2}{P_i}\right)^{\frac{n-1}{n}} - 2\right] \qquad (10.24)$$

The total work is a minimum when

$$\left(\frac{P_2}{P_i}\right)^{\frac{n-1}{n}} + \left(\frac{P_i}{P_1}\right)^{\frac{n-1}{n}}$$

has a minimum value. Differentiating with respect to P_i, which is the only variable, and setting the derivative equal to zero gives

$$P_i = \sqrt{P_1 P_2} \qquad (10.25)$$

Combining Equation 10.24 and 10.25 gives

$$(-W_g)_{\text{total}} = \frac{2n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{2n}} - 1\right] \qquad (10.26)$$

For S stages

$$\text{T.H.P.} = \frac{144}{33{,}000} P_1 V_1 \frac{Sn}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{Sn}} - 1\right] \qquad (10.27)$$

An analogous equation gives the intermediate temperature

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n'-1}{Sn'}} \qquad (10.28)$$

Typical Indicator Diagrams. Figures 10.17 and 10.18 are replots of indicator diagrams taken from the head end of a reciprocating compressor These two diagrams are typical of several made available to the writer by B. C. Thiel of Cooper-Bessemer Corporation in 1949. The two diagrams shown are for the same cylinder with different clearance volumes, the clearance pockets being closed in one case and open in the other.

The compressor indicator diagrams in Figure 10.17 are replotted on log-log scales in Figure 10.18 to illustrate the paths of the compression and expansion strokes on these scales and to show that the relationship PV^n = constant is applicable. The values of the exponent n are indicated on the plots. It will be noted that the exponents for the expansion stroke are of lower magnitude than the exponents for the corresponding compression stroke.

For most of the indicator diagrams examined by the writer, the exponent for the expansion stroke was smaller than the exponent for the compression stroke. It will also be noted, by an examination of Figure 10.18,

that the exponents are smaller on the diagram for the cylinder with the clearance pockets open. Although the values of the exponents for these paths are different, the straightness of the line indicates that the value of n is constant for each path. Data represented on Figures 10.17 and 10.18 plus similar indicator card data justify the use of the relationship PV^n = constant for polytropic compression and expansion paths.

Sample Problem Solution. Estimate the exponents and calculate the final temperature and work for the following reciprocating compressor operation. It is assumed that the compressor does not have jacket cooling and that the compression is adiabatic (no heat losses).

Gas Properties

Molecular Weight	44
Specific Gravity	1.5 (air = 1.0)
Olefins, %	50

Conditions

Initial temperature, F	100
Initial pressure, psia	15
Final pressure, psia	75
Compressor efficiency, e_c, %	75
Compressibility factor, Z	1.0

Solution

Step 1—The efficiency factor in Equation 10.17 is

$$\text{Eff Factor} = \left[1 + 1.0\left(\frac{1.0}{0.75} - 1\right)\right] = 1.333$$

Step 2—Assume final temperature = 250° F

$$t_{av} = \frac{(100 + 250)}{2} = 175°\text{F}$$

Step 3—From Figure 10.9 with t = 175, per cent olefins = 50, specific gravity = 1.5

$$k = 1.114$$

Step 4—From Figure 10.10 with $P_{av} = \frac{15 + 75}{2} = 45$

$$k = 1.114, \text{ specific gravity} = 1.5$$
$$n'_{rev} = 1.12$$

Step 5—From Figure 10.11 with $n'_{rev} = 1.12$ and Eff Factor = 1.333

$$n'_{irrev} = 1.17$$

Step 6—From Equation 10.18

$$t_2 = (100 + 460)\left(\frac{75}{15}\right)^{\frac{1.17 - 1.0}{1.17}} - 460 = 247 \text{ F}$$

The same answer is obtained from Figure 10.12. Final temperature of 247° F is close enough to the assumed 250° F so that another trial is not required.

Compression work is next computed by first finding reversible work and dividing this by 0.75.

Step 7—From Figure 9.14, with n′ = 1.12 and k = 1.114

$$n = 1.03$$

Step 8—From Figure 10.15 with $P_2/P_1 = 5$ and n = 1.03

$$F_w = 3.3$$

Step 9—Work in heat units =

$$\left(\frac{3.3}{0.75}\right)(1.0)(560) = 2460 \text{ Btu/lb mole of gas}$$

Step 10—Work in horsepower units

$$\frac{2460}{2546} = 0.965 \text{ hp/lb mole of gas}$$

If the compressor had been provided with jacket cooling, the exit temperature calculation in step 6 could be made with the n'_{rev} from Step 4. This assumes that the heat generated in the gas by the irreversibility is removed by the cooling water.

From Equation 10.18

$$t_2 = (100 + 460)\left(\frac{75}{15}\right)^{\frac{1.12 - 1.0}{1.12}} - 460 = 204 \text{ F}$$

versus 250 F assumed in Step 2. Repeat Steps 2 through 4.

Step 2 (Rev)—Assume t_2 = 200 F

$$t_{av} = \frac{100 + 200}{2} = 150°\text{F}$$

Step 3 (Rev)—From Figure 10.9 with t = 150, per cent olefins = 50, specific gravity = 1.5

$$k = 1.119$$

Step 4 (Rev)—From Figure 10.10 with P_{av} = 45, k = 1.119, specific gravity = 1.5

$$n'_{rev} = 1.125$$

From Equation 10.18

$$t_2 = (100 + 460)\left(\frac{75}{15}\right)^{\frac{1.125 - 1.0}{1.125}} - 460 = 209 \text{ F}$$

versus 200 F. assumed.

Conclusions. Charts giving isentropic exponents, n and n′, for volume and temperature changes are presented for eight gases. Also charts are included for estimating k and n′ for natural gases.

Compressor efficiencies for deviations from adiabatic and reversible conditions and for mechanical losses are defined and related to an irreversibility correction to the temperature change exponent.

Charts for calculating the temperature change, volumetric efficiency, and theoretical work of reciprocating compressors are also given and illustrated.

A distinction should be made between the positive displacement reciprocating and the centrifugal compressors because these two machines have different efficiencies and cooling arrangements.

Reciprocating machines are generally cooled by jacket water. Centrifugal compressors are not usually cooled, although some machines have internal diaphragm cooling. Jacket cooling in reciprocating compressors may remove the heat generated in the gas by the irreversibility, making the theoretical work equal to $\int VdP$.

The effect of jacket cooling on exit temperature is shown in the above sample problem.

Values of the efficiencies for different compressors are dependent on the design of the machine. This is outside the scope of this paper.

Part 11 will appear in an early issue of REFINER.

How to avoid application problems using . . .

Large Motors for Compressor Drives

1,500-hp squirrel cage induction motors used for compressor drives present unique application problems. A study of 29 cases shows how to avoid pitfalls

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THE USE of motors, 1,500-hp and larger, as drivers for refinery process equipment is no longer considered unique. However, the application problems associated with each installation are unique.

The Esso Research and Engineering Company has participated in the engineering and installation of twenty-nine squirrel cage induction motors 1500-hp and larger in the past six years (Table 1).

This article will present engineering experience gained in the application and installation of these motors. In all twenty-nine installations, a squirrel cage motor drives a centrifugal air blower or gas compressor through a speed increasing gear.

Voltage, Speed and Enclosure. Selection of motor voltage, speed and enclosure type are the first steps in applying the motor. Selection of the enclosure type should be made before the final motor horsepower is fixed. The maximum continuous horsepower available from the motor will depend on motor service factor and, therefore, on the type enclosure which is selected.

Voltage. Selection of the motor voltage requires determining the

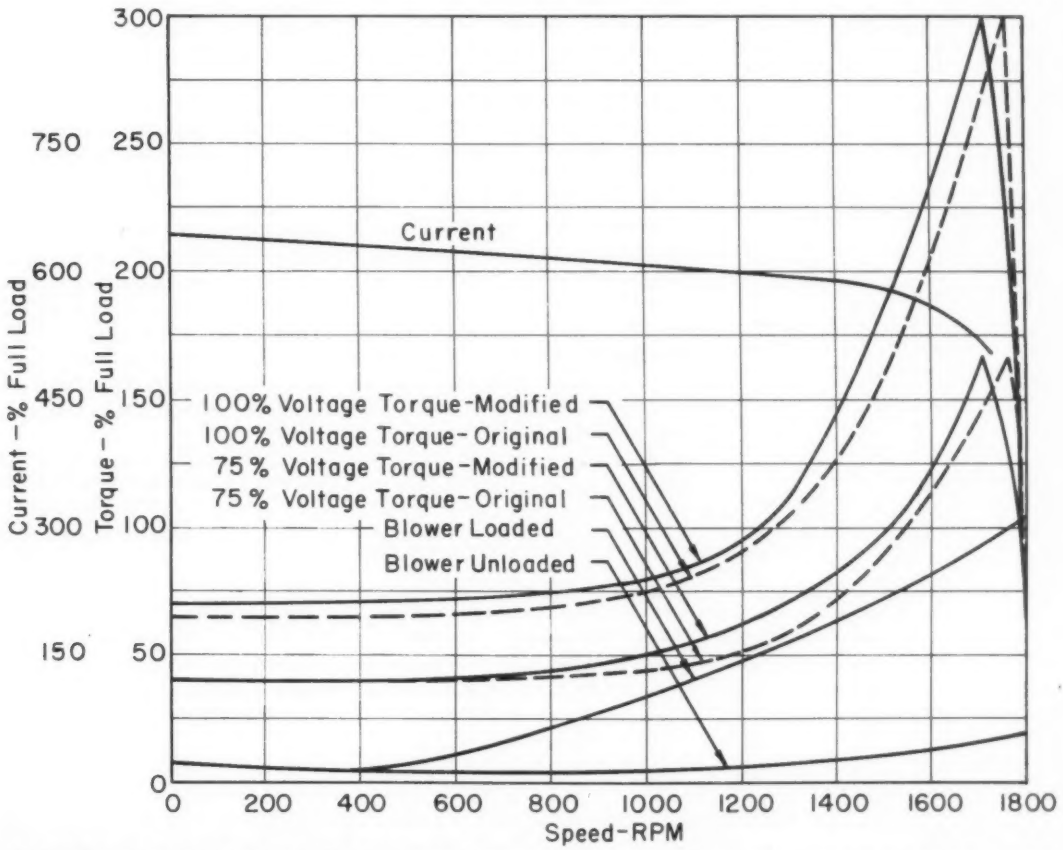

FIGURE 1—For this 3,000 hp, 1800 RPM, 2300 V motor, driving an air blower, calculated and test values checked very well.

most economical voltage level at which adequate system capacity is available to permit motor starting without excessive voltage drop. In the applications cited in Table 1, a voltage drop of 20 percent at the motor terminals was the maximum permissible calculated drop, limiting reduction in starting torque to approximately 64 percent of rated voltage value. Restrictions by the utility or by size of the refinery generating plant may limit the maximum drop to less than 20 percent. However, in the usual refinery process unit large blowers and compressors are started very infrequently once the plant has been run-in. The undesirable effects normally associated with drops as high as 20 percent have been tolerable when occurring infrequently.

Table 2 indicates the relative cost of drip-proof 1,200-rpm motors at three voltage levels. The motor cost is but one facet of any cost study for selecting voltage level. The study must compare installed cost of motor, starting equipment, transformers and power and control cables at the various levels being considered.

The higher voltage levels such as 13,200-volts are sometimes more economical overall although the cost of the motor itself is higher than at 2,300 or 4,160-volts. For example, if the refinery has a 13.8-kv distribution system, it can be more economical to install a 13,200-volt motor than to provide the primary switchgear, transformer and secondary motor control switchgear required for lower voltage motors. Operating experience at levels as high as 13,200-volts has been good, but it is not extensive compared to lower voltages. The number of manufacturers with experience at these levels is limited. Further, there are motor design considerations which limit the minimum size at which these high voltage levels can be applied. The motor manufacturer probably would not recommend a 3,000-hp, 13,200-volt motor as a first choice.

When the refinery distribution voltage is above utilization levels, for instance 23-kv or higher, the economics will usually favor the 2,300-volt motor. However, each application has its own peculiarities. An examination of the relative cost of alternate schemes sometimes favors 4,160-volts. This is true particularly where motors are in the 4,000-hp and larger sizes and short circuit levels are above 150-mva.

Speed. Table 3 indicates relative cost of 1,200, 1,800 and 3,600-rpm, 2,300-volt, drip-proof motors. Where speed increasing gears are used, the higher cost and less favorable torque characteristics of the 3,600-rpm motor eliminates its use for all practical purposes.

The motor and gear combination must provide the proper input speed to the compressor. Therefore, speed selection should consider whether the 1,800-rpm or the 1,200-rpm motor and the corresponding gear provides the more economical combination. Before selecting motor speed, motor characteristics should be obtained for both speeds. The speed-torque and speed-current curves, power factor and efficiency values should be compared and evaluated.

Enclosure. The selection of the motor enclosure type involves not only economics but also assessment of the following two factors:

- Area hazard classification
- Other area operating conditions

The determination of area hazard classifications has been aided greatly by publication of API Standard RP500. This standard provides an engineering guide for assessing the degree of hazard. The standard should be used as a guide by anyone having the responsibility for determining area classification or applying equipment in hazardous areas. It does not substitute for sound engineering judgment.

Operating conditions which also must be considered in selecting the enclosure type are exposure to airborne dust, dirt and moisture; the possibility of corrosive dust or vapors in the area; and expected maximum ambient temperature. In many cases, it is more difficult to obtain supporting data on the "other" area conditions than it is to obtain supporting data for the hazard classification.

The compressor or blower installation in a typical refinery process unit is not out-of-doors completely. Some form of shelter is provided ranging from a roof to a completely closed building. When process equipment such as a centrifugal gas compressor which is not hazardous in normal operation is present in the shelter, the hazard classification depends on the extent to which the shelter restricts ventilation. The extent of the shelter provided determines the area classification and the type of motor enclosure which should be applied.

When the first of the large motor installations cited in Table 1 was being engineered, any compresssor shelter whether completely closed or having a roof only was considered a Division 1 location. These Division 1 classifications required a suitable motor enclosure such as the totally-enclosed inert-gas filled type. Also

TABLE 1—Typical Squirrel Cage Motor Installations

Year	Horsepower	Voltage	Speed	Enclosure	Service
1953	3000 (Two)	2300	1800	TEIGF	Compressor (One) Blower (One)
1954	2000 (Two)	2300	1800	DP	Compressor (Two)
1954	3000	2300	1800	DP	Blower
1954	3500	2300	1800	DP	Compressor
1954	4000	2300	1800	DP	Compressor
1954	4000	13200	1200	TEIGF	Compressor
1954	4000	13200	1200	DP	Blower
1956	3500	4160	1800	FV	Compressor
1956	5000	4160	1200	FV	Blower
1958	9000	13200	1200	DP-M	Compressor

DP — Drip-proof
DP-M — Drip-proof with air intake from beneath motor base
FV — Force ventilated
TEIGF— Totally-enclosed inert gas or instrument air pressurized with gas-to-water heat exchanger

TABLE 2—Relative Cost At Three Voltage Levels of Drip-Proof 1200-RPM Motors

	2300-Volts	4160-Volts	13200-Volts
1500-hp	100%	114%	174%
3000-hp	100	108	155
5000-hp	100	104	145
7000-hp	100	100	133
9000-hp	100	100	129
10000-hp	100	100	129

TABLE 3—Relative Cost At Three Speeds of Drip-Proof 2300-Volt Motors

	3600-Rpm	1800-Rpm	1200-Rpm
1500-hp	124%	94%	100%
3000-hp	132	100	100
5000-hp	134	107	100
7000-hp	136	113	100
9000-hp	136	117	100
10000-hp	136	120	100

all electrically operated compressor instrumentation and control devices had to be suitable for the Division 1 classification. This complication required special measures such as separately pressurized instrumentation and control equipment areas.

About the time engineering of these installations was completed, the over-all question of area classification for gas compressor shelters was reviewed in light of all available data and experience. The conclusion was reached that a shelter with a roof having ridge ventilation and with curtain walls not extending lower than eight feet above the operating platform would be freely ventilated. Since the gas compressor would not be a source of hazard except under abnormal conditions such as an equipment failure, the decision was made to classify compressor shelters, constructed as described, Division 2 areas.

This practice has been applied for all compressor installations both in this country and abroad insofar as local conditions and regulations permit. It is felt that this compressor shelter construction more than fulfills the requirements specified in RP500 for freely ventilated areas. In accordance with the RP500 definition, any shelter having more obstruction to air passage than a "roof and one wall closed" limit is considered to have restricted ventilation and is classified Division 1.

Enclosure Applications. Motor enclosure types for compressor or blower service under shelters are applied as follows:

Division 1 Areas
- Force ventilated
- Totally-enclosed inert-gas or instrument air filled

Division 2 and Non-Hazardous Areas
- Drip-proof
- Modified drip-proof (air intake at bottom)

The force-ventilated type is preferred where a Division 1 classification is necessary. The standard drip-proof enclosure is preferred in Division 2 or in safe locations. For an outdoor installation, serious consideration would be given to using NEMA Type 2 weather-protected enclosures rather than the completely enclosed types.

In the force-ventilated or drip-proof types the cooling air passes directly over the motor winding insulation. As a rule-of-thumb a motor requires about 4,000 cubic feet per minute of cooling air per thousand horsepower. Therefore, the possibilities of airborne dust and dirt collecting on the winding must be considered carefully. Filters in the air intake will lessen the hazards of this condition. Not much can be done about moisture drawn in with the cooling air but careful selection of motor location inside the shelter can minimize the amount of wind-blown rain striking the motor.

TABLE 4—Relative Cost of Three Enclosure Types 2300-Volt 1200-RPM Motors

	Drip-proof	Force Ventilated*	Totally-Enclosed Inert Gas or Air Filled**
1500-hp.	100%	115%	183%
3000-hp.	100	113	152
5000-hp.	100	112	136
7000-hp.	100	111	134
9000-hp.	100	111	132
10000-hp.	100	110	125

* Does not include blower and duct for external air supply.
** With double tube gas to water heat exchanger. Cooling water within manufacturer's standard conditions of temperature and pressure.

On first examination, the totally-enclosed inert gas or air filled enclosure having a closed ventilating circuit using a gas-to-water heat exchanger would seem the best answer for all locations. Referring to Table 4, the cost of this enclosure runs at least 25 percent more than the drip-proof or about $27 per horsepower against $20 per horsepower for the drip-proof enclosure at the present time. Also, the auxiliary requirements of this type enclosure must be considered. It requires an external cooling water supply of good quality and high reliability. Where salt water is used or fresh water with corrosive impurities, double tube heat exchangers are necessary. Cooling water failure alarm and subsequent automatic shutdown feature and enclosure moisture detector and alarm must also be provided. In addition, an external supply of inert gas or instrument air for leakage makeup is required. All factors considered, this type enclosure requires a fairly extensive auxiliary installation. Service factor for this enclosure is normally 1.0.

The force-ventilated enclosure, in addition to the disadvantage of the contact between cooling air and the winding requires external ducting and a pressurizing blower. Standby blower arrangements are necessary since the motor is not self-ventilating on loss of the pressurizing blower. Service factor for this enclosure is normally 1.0.

The drip-proof enclosure offers a ventilating system which is not dependent on external auxiliaries. Its installed cost is the lowest of all the enclosure types. Standard drip-proof ratings above 500 rpm have a 1.15 service factor. The winding insulation is exposed to all the hazards associated with direct contact with cooling air. Also, the higher noise levels of this type may be objectionable if noise level is a design consideration.

Recognizing all of the factors mentioned, the drip-proof type has been the favored enclosure for service in shelters classified Division 2 or safe areas on the basis that it has offered adequate protection at the lowest installed cost. In most cases, air intake filters and screens have been provided. In one case, a modified drip-proof enclosure was installed with provision for future filter installation.

Motor And Driven Equipment. The coordination of motor with driven equipment involves selecting the proper motor horsepower, comparison of motor and driven equipment speed-torque curves, determination of required starting time, effect of momentary voltage losses, provision for thrust conditions by use of the proper coupling and end play limits, and coordination of bearing lubrication requirements.

Selecting Horsepower. Motor horsepower required to operate the compresor or blower is dictated by process plant operating conditions. Usually there will be minimum conditions, normal (design) conditions and maximum conditions. Economic sizing of the motor depends on exercising good judgment when determining capacity to be provided in the motor over the usual maximum operating conditions. Two other factors should be considered—capability of the compressor casing and likelihood that plant requirements will dictate a future change in rotor to take advantage of casing capability.

Comparison. An early appraisal of motor and driven equipment speed-torque characteristics, particularly at the reduced voltage occurring during starting, is necessary. The following data should be obtained:

Motor

- Speed-torque curve.

- Speed-current curve.
- Moment of inertia (Wr^2).
- Locked rotor power factor.
- Time constant for open circuit voltage (when motor control will use delayed transfer to alternate source on voltage loss).

Driven Equipment

- Unloaded speed-torque curve. (Zero flow through compressor)
- Loaded speed-torque curve. (Compressor design point)
- Moment of inertia including gear.
- Gear ratio.

The voltage drop during starting should be calculated using the speed-current data, locked rotor power factor and the distribution system constants. Speed-torque values at this reduced voltage can be calculated assuming that the torque varies as the voltage squared. These values are compared to driven equipment curves.

In comparing speed-torque characteristics, driven equipment torque requirement at any speed must not exceed 95 percent of motor torque at that speed. Also, the driven equipment speed-torque curve for the loaded condition is used. If less than 5 percent torque is available, it is considered doubtful that the motor can successfully accelerate. Theoretically 1 percent difference should permit acceleration, however, 5 percent provides the margin for calculation inaccuracies.

Why use the driven equipment speed-torque curve for the loaded condition in this comparison? While under most circumstances acceleration without load is normal, it has been found that during process emergencies and sometimes due to errors in procedure, the motor will have to accelerate a loaded machine. Also, if the motor is required to reaccelerate the driven equipment after a decrease in speed following a voltage loss, reacceleration will follow the loaded curve. Admittedly, the worst conditions are considered. The experience has been that use of the driven equipment loaded curve has not increased required motor horsepower. It has in one or two cases required that the motor design provide additional torque in the 60 percent to 80 percent speed range.

Figure 1 illustrates a case in which the motor design was modified to provide additional torque in the 60 to 80 percent speed range. This was done at a very small sacrifice in efficiency.

Starting Time. If a motor has sufficient torque available at all points along the speed-torque curve, the starting time should be calculated. Equation 1 in the appendix can be used for this calculation.

In many cases, the motor has been supplied from a substation having a split bus section with normally open tie circuit breaker. The tie breaker closes automatically after a voltage loss on one bus. This automatic closing is delayed until bus residual voltage decays to 25-35 percent rated voltage. The time required for the voltage decay on a bus serving a large motor can be approximated using Equation 2 in the appendix. Using the voltage decay time, an approximation of motor speed at time of voltage restoration can be made using Equation 1. Equation 2 uses the motor open-circuit voltage time constant and is applicable where a single large motor is supplied by a bus section since the bus time constant will be very nearly equal the motor time constant. Other loads connected to the bus affect the bus time constant. Reference 2 contains a more detailed analysis of delayed automatic transfers of large induction motors and of the open-circuit time constants.

For the installation covered by Figure 1, calculated and test values of voltage drop on starting, times for automatic closing of the bus tie breaker and for reacceleration and motor speed after voltage loss checked very well. Actual starting time was 20 seconds against 27 seconds calculated. This improvement was due to the fortunate circumstance that actual motor torque was greater than design values shown in Figure 1.

End Float Couplings. To guard against transmitting thrust continuously from motor to driven equipment bearings, gear-type flexible couplings with the limited end float provision are used. The following requirements are specified for all large motors:

- The coupling is required to have a minimum ¼ inch end float.
- The motor end float must exceed coupling end float by ¼ inch, making minimum permissible motor end float ½ inch.
- The motor magnetic center must be within $\frac{3}{32}$ inch of motor geometric center.
- Motor centering force must be sufficient to return rotor to magnetic center against friction of a new properly lubricated coupling.
- The momentary end thrust transmitted by the motor to the coupling and thus to the driven equipment must not exceed 100 pounds per thousand horsepower. (This provision covers thrust transmitted when "breaking away" the engaged coupling gear teeth from their rest position or when the coupling separators touch on starting.)

These requirements have been specified for motors purchased in this country and abroad and have been acceptable to both motor and mechanical equipment suppliers.

Bearing Lubrication. Large motor bearings are the oil-lubricated sleeve type. Forced feed lubrication is normally required for 3,600-rpm motors 1000-hp and larger, 1800-rpm motors 2500-hp and larger, 1,200-rpm motors 4,000-hp and larger.

In most cases a common forced feed system supplies both motor and driven equipment. The normal and auxiliary oil pumps are mounted on the compressor baseplate. Lube oil pumps and lube oil reservoirs must have sufficient capacity to handle the requirments for both users. The following data are required from the motor manufacturer:

- Gallons per minute of lubricating oil required.
- Total Btu oil cooling capacity required.
- Oil pressure required at motor bearings.

Lube system pressure switch interlocks are required in motor starting and automatic shutdown circuits.

Starting Duty Cycle. Starting times for large motors driving high inertia loads such as centrifugal blowers and compressors can be twenty seconds or longer. The motor draws locked rotor current for most of this period. These high currents maintained for such long periods cause winding and rotor temperature to rise rapidly. These effects, plus the other effects of starting on winding end turns and bracing, require that a starting duty cycle be established for the large

motor. The starting cycle should be included in the plant operating manual, and the plant operators should be briefed on the importance of complying with its requirements.

In some of the first applications of motors covered in Table 1, the permissible starting cycle was not established until after the motor design had been made. It was obvious that a much better approach would provide the motor manufacturer with the required starting duty cycle and conditions during starting prior to his final motor design. Discussions were held with motor manufacturers regarding permissible starting cycles, assuming certain system and operating limitations which were considered typical of blower and compressor service.

As as result of these discussions, an arbitrary starting duty cycle was established. A condensed version of this cycle is provided in Table 5. It should be noted that three successive starts is the maximum required. This cycle is based on the following:

1. Driven equipment Wr^2 (referred to motor shaft) is less than five times motor Wr^2.
2. Voltage at motor terminals is not less than 80 percent motor rated voltage.
3. Motor is started from rest with driven equipment unloaded.
4. Motor comes to rest before restarting and there are five minutes between restarts.
5. Motor must be capable of accelerating the load under assumptions stated above in 20 seconds maximum.

One additional requirement covering reacceleration duty was also established as follows:

> If motor is running, it shall be capable of reaccelerating load upon reapplication of not less than 80 percent rated motor voltage failure not exceeding four seconds. The driven equipment is not unloaded during the voltage failure.

During the past five years this starting duty has been specified for motors manufactured both in this country and abroad. There has been no difficulty in obtaining motors to meet these requirements. Most standard motor designs meet the requirements and in some cases the manufacturer's permissible starting cycle exceeds these requirements.

TABLE 5—Start Permitted

Minutes Running Since Max. Temperature	Minutes Idle Since Max. Temperature	Allowable Successive Starts
40	0	1
0	120	1
80	0	2
0	240	2
80	120	3
0	360 (or more)	3

Coordination With Utility. All 29 installations of large motors use across-the-line starting. Voltage drops of 20 percent on starting, lasting for 20 seconds approximately have been acceptable to the public utility. This is undoubtedly due to the very infrequent starting of the large motors once plant start-up is completed.

In each case, the public utility supplying the refinery was advised of the proposed installation as early in the engineering phase as possible. A preliminary relay coordination was also worked out in conjunction with the utility for the entire system from motor circuit breaker back to utility supply breaker. This was also done early in the engineering phase. These procedures are recommended.

Protective Relaying. The large motor requires protection beyond that normally associated with smaller motors. The protective relays and devices listed below have been applied for each installation. In all 29 motor installations, the motor controller has been a drawout circuit breaker in metalclad switchgear.

Protective relaying has been provided as follows:

1. Three over-current relays with long-time characteristics or two thermal relays and one long-time relay, each with instantaneous trip. Relays are set to pick up at 175-200 percent motor full load current and to provide the required accelerating time at locked rotor current value. Instantaneous trips are set between 150 percent and 200 percent of locked rotor current.
2. On grounded systems, a residually-connected overcurrent relay with short time characteristics and without an instantaneous trip is used. The instantaneous trip would be used if a core type current transformer encompassing all three phase conductors was used. The ground relay is set to pick up at 10-25 percent motor full load current and to trip at 0.4 seconds at maximum ground fault current. The instantaneous element, if used, would be set below maximum ground fault value.
3. One time delay undervoltage relay. Relay is set to pick up at 75-80 percent rated bus to voltage. Time delay setting for motors which reaccelerate after time delay automatic transfer is 5 seconds at zero voltage when transfer time is 4 seconds maximum. If motor does not reaccelerate, relay is set to provide one second delay at zero voltage.
4. Differential relays, usually slow speed, or split winding relaying.

In most cases using differential relays, the slow speed relay has been applied. It is probable that the high speed relay will be used in future applications particularly if the motors are 4000-hp or larger. The high speed relay will operate in three cycles or less, the slow speed 6-8 cycles.

Split winding relays have been used in five or six installations. This relaying provides turn-to-turn short circuit and open-circuit protection in addition to phase-to-phase and phase-to-ground short circuit protection. It is applicable on those motors having windings with multiple current paths in each phase. Current transformers at the motor are not required by split-winding protection. However, a current transformer is required in the switchgear for each current path per phase. Multiple phase conductors are also required between motor terminals and switchgear.

The split-winding protection probably provides a wider scope of protection than differential but may not provide the fast tripping in all cases provided by differential relays. Maximum unbalance current during motor starting and minimum fault current unbalance must be determined to size current transformers and select the relay. When the difference between these two values is small the relay application becomes difficult. In at least one case, it was necessary to introduce a 6-cycle time delay to prevent relay operation by asymmetrical currents during motor starting or on contribution to external faults. Normally, a short-time overcurrent relay can be used as the current unbalance measuring device. However, where the intentional time delay was introduced, an instantaneous relay triggered by the time delay relay was installed.

Other Protective Devices. Resistance temperature detectors have been provided on all large motors as the first-line overload protection. The detector is wired to thermometer—protectors which actuate visual and audible alarms. The alarm points used are 120C for Class "B" insulated windings, 95C for Class "A" insulated windings.

Bearing temperature relays are provided on the large motors. A problem with this device is whether to alarm or trip. Most manufacturers feel that the alarm provides little or no protection. However, plant operators feel just as strongly about unscheduled shutdowns. Some installations have been set for alarm and some to trip. A maximum permissible bearing temperature of 100C has been used and would be the shutdown value. For alarm the set point would be determined in the field and would be 10 degrees above normal operating temperature but in no case more than 100 C.

The forced feed lubrication system requires a pressure switch contact which closes on increasing pressure and a contact which closes on decreasing oil pressure. The increasing pressure contact is wired in series with the motor start button to prevent starting unless sufficient lube pressure is available. The decreasing pressure contact trips the motor circuit breaker on falling lube pressure. This contact is normally wired to a time delay relay in order to prevent false tripping on pressure dips or while the auxiliary pump is building up pressure. A time delay relay providing eight second delay pickup and instantaneous dropout has been used.

Operating Experience. Information has been provided on the application practices developed during the engineering of 29 applications of motors above 1,500 horsepower. What has been the experience with these installations?

Over-all experience has been very good. There have been only two cases of trouble which caused unscheduled shutdowns. Both cases resulted from motor short circuits.

One winding short circuit occurred in a 3,000-hp 2,300-volt totally-enclosed inert gas filled motor after about nine months of operation. This motor had a single tube heat exchanger and a water leak occurred due to tube corrosion. A complete set of coils ordered as spare parts was available and the motor was completely rewound in the manufacturer's nearby shop and returned to service in 21 days. The plant was able to operate at reduced capacity while the motor was out of service. Double tube heat exchangers were installed shortly thereafter in this motor and a second motor of similar construction.

The second short circuit occurred in the terminal box of a 5,000-hp 4,160-volt force-ventilated motor about one year after installation. This short circuit occurred under very unusual circumstances. During extremely cold weather, condensation formed on the outside of the ventilating duct where it ran through the warm compressor house. The condensation dropped down on the motor housing and ran into the ungasketed sheet metal terminal box. The water entering the box caused a short circuit to ground in one motor lead. Fortunately, the damage was repaired on the spot with only about eight hours shutdown.

There have been minor troubles resulting from faulty bearings and misalignment which were corrected during scheduled shutdowns. In one case, broken rotor bars were discovered during inspection of a rotor for bearing trouble. The broken bars evidently were a result of a manufacturing defect and were repaired by the manufacturer at his local service shop.

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LITERATURE CITED

[1] Recommended Practice for Classsification of Areas for Electrical Installations in Petroleum Refineries, *American Petroleum Institute Standard RP500, 2nd Edition, January 1957*, American Petroleum Institute, Division of Refining.

[2] Problems Encountered in Automatic Transfer of Large Induction Motors in Industrial Applications, R. O. Bigelow, C. Auty, *AIEE Conference Paper*, Summer General Meeting, Swampscott, Mass., June 27-July 1, 1955.

APPENDIX

Equation 1—Approximation of motor starting time can be obtained by summation of starting time increments calculated for several speed intervals. Five or six speed intervals should be used. Use small intervals where accelerating torque changes are large, large intervals when torque changes are small. For deacceleration, calculate Δt from Equation 2 and solve for the expression $(rpm_1 - rpm_2)$. Since rpm_1 is motor full speed, rpm_2 is motor speed when bus tie closes.

$$\Delta t = \frac{3.25\ (10)^{-3}\ Wr^2\ (rpm_1 - rpm_2)}{\Delta T}$$

Δt—incremental acceleration time in seconds.

Wr^2—rotational moment of inertia of compressor, gear and motor in lb-ft^2. Driven equipment values referred to motor shaft speed.

$rpm_1 - rpm_2$—speed interval

ΔT—accelerating torque in ft. lb. (difference between motor torque and load torque) use average value between points rpm_1 and rpm_2. For deacceleration, use driven equipment torque from loaded curve (retarding torque).

Equation 2—Approximation of time for tie breaker closing in delayed automatic transfer schemes can be obtained. The approximation is valid for installations where one large motor is supplied from a bus section and other single motor loads are relatively small—for instance $^1/_{10}$ the large motor size. Use the calculated time as Δt in Equation 1.

$e^{-\frac{t}{a}}$ = per unit open-circuit voltage

e—natural logarithm

a—time in seconds for motor open circuit voltage to decay to 0.367 rated voltage (motor time constant)

t—time in seconds for open-circuit voltage to decay to required per unit value (setting of residual voltage relay)

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For Multicomponents . . .

Rigorous Distillation Method

- **Minimum of trial and error**
- **Rapid convergence**

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A COMPLETELY rigorous, analytical distillation calculation method is described which results in rapid convergence to a final solution with a minimum of trial and error calculation. The method is applicable to all tower arrangements including absorbers, strippers, and fractionating towers with multiple feeds, sidedraws or other modifications.

The basic steps of the method are as follows:

1. Develop fractionation equations for each section of the tower.

2. Make primary assumptions of number of trays, reflux ratio, sidedraw rates, steam rates, lean oil rates, etc.

3. Estimate the molar vapor and liquid rate and temperature for each tray in each section of the tower.

4. Simultaneously solve the fractionation equations for the composition of each component in the overhead and bottoms product. Calculate the composition of non-distributed components on trays around the feed tray.

5. Verify the estimation of vapor-liquid rates and tray temperature by a tray to tray calculation from each end of the tower.

6. Reestimate the vapor-liquid and tray temperature profile and repeat steps (4) and (5) until the vapor-liquid and tray temperature profile is constant and a feed plate match is obtained in the tray to tray calculation.

Although the above steps appear tedious, in actual practice a tower with either few or many trays can be rapidly calculated with a minimum of effort. Usually only two or three trials are required. After the first trial the tray to tray calculation is simplified as usually only the profiles around the feed tray require adjustment. As an example, a tower was recently calculated by this method, having two reflux streams, a side reboiler and a temperature gradient of 220° across the tower. A satisfactory rigorous solution was obtained in three trials and in much less time than by other methods.

Feed plate meshing is eliminated because product compositions are obtained by solving the fractionation equations simultaneously. Convergence is rapid because a moderate error in assuming the vapor-liquid rates and tray temperatures affect product compositions very slightly. As the product compositions become more accurate, the vapor-liquid and tray temperature profiles by a tray to tray calculation also become more accurate. The product compositions rapidly approach their correct value and a solution is obtained.

The fractionation equations, referred to in step 1, are an extension of the work done by Edmister[1] and others.[2,3,4] Two important modifications are used. One is the use of the fractionation factor $S = \frac{KV}{L}$ as the basis of all equations, whether absorption, stripping or enriching be the mechanism involved. The second modification is the concept of the equilibrium feed tray. By this concept we state that the vapor from the feed tray

is in equilibrium with the liquid leaving the feed tray. Referring to Figure 1, the assumption is that $\bar{v}_n$ and $\bar{l}_n$ are in equilibrium. The feed condition and enthalpy are taken into account since the section of the tower pictured must be in heat and material balance. This is an ideal concept which is congruous with the assumption of the equilibrium tray used as the basis of tower calculations. The efficiency of the equilibrium feed tray may differ from the overall tower efficiency depending upon the condition of the feed. The effect of any difference, however, is small and for all purposes can be neglected.

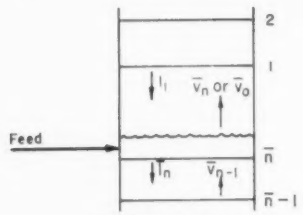

FIGURE 1

The alternative concept is that of flashed feed as used by Edmister and others. Although it may be argued that in some cases this concept will more closely approach the actual condition existing at the feed tray in a tower, it is an approximate concept unless heat transfer and mixing mechanisms around the feed tray are known in detail. Consideration of both concepts indicates that the equilibrium feed tray concept is no less accurate, and adds greatly to the flexibility and ease of calculation.

The development of the generalized fractionation equation is shown below. The generalized equation is converted to a specific equation for a section of a tower by combination with appropriate material balance and equilibrium relationships at the product end of a section. A section of a tower consists of those trays that lie between product and/or feed streams. A specific equation for the top and bottom of a conventional fractionating tower is developed below. Note that trays must always be numbered from the bottom tray up of each section in order to be consistent with the equations. A small (—) over a quantity will designate that it refers to the bottom section of a conventional tower to differentiate from quantities in the top section. Specific equations for other possible tower arrangements are tabulated in the Appendix.

I. The Generalized Fractionation Equation

Consider the section of a fractionating tower pictured in Figure 2.

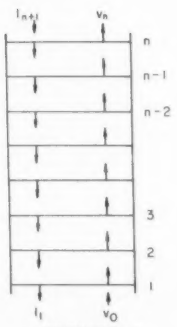

FIGURE 2

Starting from the bottom and combining equilibrium and material balances,

$$L_2x_2 = V_1y_1 + L_1x_1 - V_oy_o$$

$$K_1x_1 = y_1$$

$$x_2 = \frac{V_1K_1x_1}{L_2} + \frac{L_1x_1 - V_oy_o}{L_2}$$

$$L_3x_3 = V_2K_2x_2 + L_1x_1 - V_oy_o$$

Substituting,

$$L_3x_3 = \frac{V_2K_2}{L_2}V_1K_1x_1 + \frac{V_2K_2}{L_2}(L_1x_1 - V_oy_o) + L_1x_1 - V_oy_o$$

$$L_4x_4 = V_3K_3x_3 + L_1x_1 - V_oy_o$$

Substituting,

$$L_4x_4 = \frac{V_3K_3}{L_3}\frac{V_2K_2}{L_2}V_1K_1x_1 + \frac{V_3K_3}{L_3}\frac{V_2K_2}{L_2}(L_1x_1 - V_oy_o) + \frac{V_3K_3}{L_3}(L_1x_1 - V_oy_o) + L_1x_1 - V_oy_o$$

Then for n trays,

(1) $L_{n+1}x_{n+1} = V_1K_1x_1(S_2S_3 \ldots S_n) + (L_1x_1 - V_oy_o)(S_2S_3 \ldots S_n + S_3S_4 \ldots S_n + \ldots + S_n + 1)$

where $S_i = \frac{K_iV_i}{L_i}$

By over-all material balance

$$V_oy_o + L_{n+1}x_{n+1} = V_ny_n + L_1x_1$$

and $$x_1 = \frac{1}{L_1}(V_oy_o + L_{n+1}x_{n+1} - V_ny_n)$$

Substituting in (1)

$$L_{n+1}x_{n+1} = V_oy_o(S_1S_2S_3 \ldots S_n) + (L_{n+1}x_{n+1} - V_ny_n)(S_1S_2S_3 \ldots S_n) + (L_{n+1}x_{n+1} - V_ny_n)(S_2S_3 \ldots S_n + S_3S_4 \ldots S_n + \ldots + S_n + 1)$$

(2) $L_{n+1}x_{n+1} = V_oy_o(S_1S_2S_3 \ldots S_n) + L_{n+1}x_{n+1}(S_1S_2S_3 \ldots S_n + S_2S_3 \ldots S_n + \ldots + S_n + 1) - V_ny_n(S_1S_2S_3 \ldots S_n + S_2S_3 \ldots S_n + S_3S_4 \ldots S_n + \ldots + S_n + 1)$

(3) By definition let $\phi_1S = (S_1S_2S_3 \ldots S_n + S_2S_3 \ldots S_n + S_3S_4 \ldots S_n + \ldots + S_n + 1)$

(4) And $\phi_2S = (S_1S_2S_3 \ldots S_n)$

Then

(5) $L_{n+1}x_{n+1} = V_oy_o(\phi_2S) + L_{n+1}x_{n+1}(\phi_1S) - V_ny_n(\phi_1S)$

Or

(6) $V_oy_o(\phi_2S) = V_ny_n(\phi_1S) - L_{n+1}x_{n+1}(\phi_1S - 1)$

Or

(7) $v_o(\phi_2S) = v_n(\phi_1S) - l_{n+1}(\phi_1S - 1)$

II. Specific Equation—Example

A. Enriching Section With Liquid Overhead Product

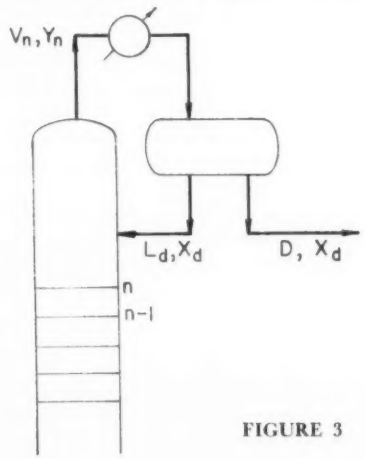

FIGURE 3

By material balance around the condenser,

$$V_n y_n = L_d X_d + D x_d \qquad \text{Note } L_d x_d = L_{n+1} x_{n+1}$$

Substituting in the general equation (6)

$$V_o y_o\ (\phi_2 S) = (L_d x_d + D x_d)\ (\phi_1 S) - L_d x_d\ (\phi_1 S - 1)$$

$$V_o y_o = D x_d \frac{(\phi_1 S)}{(\phi_2 S)} + \frac{L_d D x_d}{D(\phi_2 S)}$$

$$(8)\quad \frac{v_o}{d} = \frac{(\phi_1 S)}{(\phi_2 S)} + \frac{L_d}{D(\phi_2 S)}$$

B. Stripping Section With a Reboiler

By Material Balance Around the Section

$$\overline{L}_{n+1} x_{n+1} + F Z_f = \overline{V}_n y_n + B x_b$$

Note $\overline{V}_b y_b = \overline{V}_o y_o$

Substituting in Equation (6) and noting that $L_{n+1} x_{n+1}$ in Equation (6) is equivalent to $\overline{L_{n+1}} x_{n+1} + F Z_f$,

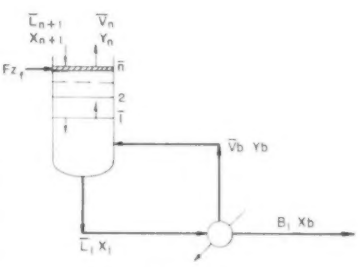

FIGURE 4

$$\overline{V}_b y_b\ (\overline{\phi_2 S}) = \overline{V}_n y_n\ (\overline{\phi_1 S}) - (\overline{V}_n y_n + B x_b)\ (\overline{\phi_1 S} - 1)$$

$$\overline{V}_b y_b\ (\overline{\phi_2 S}) = \overline{V}_n y_n - B x_b\ (\overline{\phi_1 S} - 1)$$

$$\overline{V}_n y_n = \overline{V}_b y_b\ (\overline{\phi_2 S}) + B x_b\ (\overline{\phi_1 S} - 1)$$

Since $y_b = K_b x_b$

$$\overline{V}_n y_n = \frac{\overline{V}_b K_b B x_b}{B}\ (\overline{\phi_2 S}) + B x_b\ (\overline{\phi_1 S} - 1)$$

$$(9)\quad \frac{\overline{v}_n}{b} = \frac{\overline{V}_b K_b}{B}(\overline{\phi_2 S}) + \overline{\phi_1 S} - 1$$

An additional equation that permits Equations (8) and (9) to be solved simultaneously is developed from the equilibrium feed tray concept.

Defining the right side of Equations (8) and (9) as (R) and (S), respectively,

$$(10)\quad d = \frac{v_o}{(R)} \text{ and } b = \frac{\overline{v}_n}{(S)}$$

Dividing the two equations and noting that $\overline{v}_n$ is the same as v_o by the equilibrium tray concept (see Figure 1), $\frac{b}{d} = \frac{(R)}{(S)}$. Although this equation would permit a solution for product compositions, a desired distillate rate (or bottoms rate) would not be obtained unless the correct vapor-liquid and temperature profiles had been fortuitously assumed. By introducing a correction factor, *C*, it is possible to derive an equation that can be solved in terms of a desired distillate rate. The equation becomes,

$$(11)\quad \frac{b}{d} = \frac{C(R)}{(S)}$$

since $b + d = f$

$$(12)\quad d = \frac{f}{1 + \frac{b}{d}} = \frac{f}{1 + \frac{C(R)}{(S)}}$$

Setting the distillate rate, D, where $D = \Sigma d$,

$$(13)\quad D = \Sigma d = \sum \frac{f}{1 + \frac{C(R)}{(S)}}$$

Using Equation 13, and appropriate values of (R) and (S) for each component, a value of *C* is assumed by trial and error until the desired quantity *D* is obtained. In initial trials of a problem, *C* may be quite different from 1.0 but will rapidly approach 1.0 in succeeding trials. When the feed plate composition by tray to tray computation from the top tray to the feed tray and from the bottom tray to the feed tray exactly match at convergence of a problem, *C* will equal 1.0 (subject to slight cumulative errors in summating the fractionation equations). In a hand calculation of a problem, an acceptable tray to tray solution will usually be obtained before *C* exactly equals 1.0.

For the problem of multidraw or multifeed towers, additional specific fractionation equations are developed for the center sections. A single *C* value can be used or separate *C* values can be used to mesh each section. The equations for simultaneous solution of multidraw towers can be developed without much difficulty, but will not be covered in this paper.

Non-distributed components are very light or very heavy components whose concentration decreases very rapidly below or above the feed tray, respectively, and whose composition in the bottoms or overhead product would be less than say 10^{-6} mole fraction. Rather than compute concentrations and *S* values for these components in sections where their concentration is negligible, it is simpler to introduce these components into the tray to tray calculation at the point where their concentration becomes significant. The concentration of non-distributed components at the feed tray can be calculated by using Equation (10) in rearranged form.

$$(14)\quad v_o = d(R)$$

$$(15)\quad \overline{v}_n = b(S)$$

1. For the light non-distributed component in the bottom section: Assuming that the correction factor *C* applies equally to (R) and (S) and since $\overline{v}_n = v_o$,

$$(16)\quad \overline{v}_n = d\ \overline{C(R)}.$$ As b is negligible for these components,

$$(17)\quad \overline{l}_n = \frac{\overline{v}_n}{\overline{S}_n} = v_{n-1}, l_{n-1} = \frac{\overline{v}_{n-1}}{S_{n-1}} = \overline{v}_{n-2}, \text{ etc.}$$

By using equations (16) and (17) and appropriate values of *S*, the composition of light non-distributed components can be calculated for the feed tray and the

trays below the feed until the concentration is small enough to be neglected. The concentration thus calculated is inserted into the tray to tray calculation for the bottom section at the appropriate tray.

2. For the heavy non-distributed component in the top section: Similarly as above,

(18) $v_o = \frac{b(S)}{\sqrt{C}}$. Since d is negligible for these components,

(19) $l_1 = v_o, v_1 = S_1 l_1 = l_2, v_2 = S_2 l_2 = l_3$, etc.

Equations (18) and (19) permit calculation of the concentration of heavy non-distributed components on the feed tray and trays above the feed. These values are inserted into the tray to tray calculation for the top section at the proper tray. The calculation should be repeated after every trial as the concentrations will change as the profiles are corrected.

Although equations (16) and (18) are approximate unless convergence has been reached and C = 1.0, they are satisfactory for calculating the concentration of non-distributed components. The equations should not be used to calculate the composition of key and distributed components at the feed tray.

The procedure for calculation of a conventional tower:

Step 1. The fractionation equation for the top section (Equation 6) is

$$\frac{v_o}{d} = \frac{(\phi_1 S)}{(\phi_2 S)} + \frac{L_d}{D(\phi_2 S)} = (R).$$

The fractionation equation for the bottom section (Equation 7) is

$$\frac{\overline{v_n}}{b} = \frac{V_b K_b}{B}$$

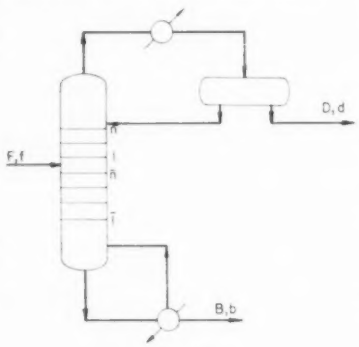

FIGURE 5

$$\overline{(\phi_2 S)} + \overline{(\phi_1 S)} - 1 = (S)$$

Step 2. From preliminary calculations estimate the product split and make an over-all heat balance. Develop *K* data, etc. Assume or calculate: Number of trays in each section, L_D, D, $\overline{V}_b$, B & K_b.

Step 3. Estimate a vapor-liquid and temperature profile for the tower (Plot these quantities versus tray number). For the first trial constant molal overflow and a linear temperature gradient can be assumed unless a better source for estimating the profiles is available. Calculate *S* for every tray. Note that $S_i = \frac{K_i V_i}{L_i}$ is calculated for each component and is based on the tray temperature, and the total molal liquid and molal vapor rate for the tray. Evaluate the quantities $\phi_1 S$ and $\phi_2 S$ for each component in the top and bottom sections by calculating the series expression defined in equations (3) and (4). If constant molal overflow and constant temperature applies so that $S_1 = S_2 = S_3 = S_n = S_{avg}$, rather than evaluating the series expression, use the expression

(20) $\phi_1 S = \frac{S_{n+1_{avg}} - 1}{S_{avg} - 1}$ and

(21) $\phi_2 S = S_{n_{avg}}$. If there is variation in S but accuracy is not essential, S_{avg} can be evaluated in terms of the terminal S values, S_1 and S_n, per formulae by Edmister[1] using a two tray section concept or by assuming a geometric gradient as per Sheldon[5] or by a simple arithmetic average. It is highly recommended that the series expressions (equations 3 and 4) be used whenever possible because of the much greater accuracy obtained with only slightly more calculation required than with short cuts.

Step 4. Evaluate the quantities (R) and (S) for each component (except non-distributed components) in the top and bottom section by using the fractionation equations defined in Step 1. Simultaneously solve the fractionation equations by substituting in Equation (13), $\sum \frac{f}{1 + \frac{C(R)}{(S)}} = D$. Assume a value of *C* by trial and error so that the summation equals the desired overhead product rate, *D*. Calculate d for each component from Equation (12) $d = \frac{f}{1 + \frac{C(R)}{(S)}}$ and calculate b = f — d. Calculate the composition of the non-distributed components around the feed tray using equations (16) and (17) for light components and equations (18) and (19) for heavy components. Calculate concentrations of non-distributed components by proceeding from the feed tray until the tray is reached where the concentrations has become negligible, say < 0.1 Mole/hour.

Step 5. Verify the assumed vapor-liquid and temperature profiles by making a tray to tray calculation for the bottom and top section. Start with the overhead and bottoms products calculated above and work from the ends of the tower to the feed tray. A heat balance should be made on every tray. If overflow is reasonably constant, however, the heat balance can instead be checked every few trays without introducing significant error. A tray to tray calculation with heat balances requires trial and error to determine the next tray temperature and overflow rate. The fastest and easiest method is usually to assume the next tray temperature, calculate the overflow, and then check the assumed tray temperature by a dew point or bubble point calculation. Complete the tray to tray calculation working from both ends of the tower to the feed tray unless it becomes obvious that the profiles assumed in the solution of the fractionating equations are grossly different from those calculated by tray to tray. In either case plot the vapor-liquid and temperature profiles versus tray number. Smooth the temperature profile to eliminate any mismatch at the feed tray and adjust the vapor-liquid profiles if deemed necessary.

Using the new vapor-liquid and temperature profiles, repeat steps 3, 4 and 5 as necessary until convergence is obtained. At convergence and the final solution, the assumed profiles will agree with the profiles calculated by tray to tray and the feed

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tray composition by the top-down calculation will match the feed tray composition by the bottom-up tray to tray calculation.

To further illustrate the method the numerical calculation of a depropanizer tower is presented below. The problem has been previously calculated by Edmister[1] to illustrate the Lewis-Matheson and Thiele-Geddes methods with the assumptions of constant molal overflow. In order to conserve space, constant molal overflow is also assumed here although it must be realized that this would not be valid for designing a commercial tower and is not a requirement for using this method.

SAMPLE PROBLEM

Depropanizer Tower (Note: Data taken from Edmister,[1] Example 27 and 28). Feed = 100 Moles/hr.

Comp.	Feed	
C_1	26.0	Feed Flash
C_2	9.0	Vapor—66.0 Moles/hr.
C_3	25.0	Liquid—34.0 Moles/hr.
C_4	17.0	
C_5	11.0	Assume Constant Molal Overflow.
C_6	12.0	Let $D = 59.9$ Moles/hr., $\frac{Ld}{D} = 1.503$.
	100.0	Let Ld = 90.0 Moles/hr.

Fractionation Equations

Top Section With Vapor Overhead Product

$$\frac{V_o}{d} = \frac{L_d}{DK_d\phi_2 S} + \frac{\phi_1 S}{\phi_2 S} = (R)$$

Bottom Section

$$\frac{\overline{v_n}}{b} = \frac{V_b K_b \overline{\phi_2 S}}{B} + \overline{\phi_1 S} - 1 = (S)$$

TOP SECTION

Temp., F. / Comp.	63° K_d	105° K_6	119° K_5	123° K_4	132° K_3	144° K_2	160° K_1
C_1	7.7	9.80	10.2	10.5	10.93	11.44	12.3
C_2	1.5	2.05	2.24	2.29	2.45	2.63	2.94
C_3	0.5	0.76	0.84	0.88	0.95	1.040	1.17
C_4	0.16	0.30	0.35	0.372	0.417	0.473	0.553
C_5	0.054	0.105	0.141	0.1435	0.166	0.1955	0.24
C_6	0.0144	0.04	0.052	0.0563	0.0665	0.0811	0.105

Comp.	S_1	S_2	S_3	S_4	S_5	S_6	S_6S_5	$S_6S_5S_4$
C_1	20.49	19.06	18.21	17.49	16.99	16.33	277.45	4852.6
C_2	4.90	4.38	4.08	3.815	3.732	3.415	12.745	48.622
C_3	1.949	1.733	1.583	1.466	1.399	1.266	1.771	2.596
C_4	0.921	0.788	0.695	0.620	0.582	0.500	.2915	.1807
C_5	0.400	0.3257	0.2766	0.2391	0.235	0.175	.0411	.00983
C_6	0.175	0.1351	0.1108	0.0938	0.0866	0.067	.00580	.00054

Comp.	$S_6 \ldots S_3$	$S_6 \ldots S_2$	$\frac{\phi_2 S = S_6 \ldots S_1}{S_6 \ldots S_1}$	$\phi_1 S$	$\frac{L_d}{DK_d}$	$\frac{L_d}{DK_d\phi_2 S}$	$\frac{\phi_1 S}{\phi_2 S}$	(R)
C_1	88,366	1,684,260	34,510,500	36,288,400	0.1952	.00000	1.0515	1.0515
C_2	198.38	868.9	4258	5391	1.002	.000235	1.2661	1.2663
C_3	4.109	7.121	13.88	31.74	3.006	.2166	2.2867	2.5033
C_4	.1256	.09897	.09115	2.288	9.394	103.06	25.10	128.16
C_5	.00272	.00089	.00036	1.2299	27.83	77,306	3416	80,722
C_6	.00006	.00001	.00000	1.0734	104.4	$>10^6$	$>10^6$	$>10^6$

Note that trays are numbered from the bottom tray upwards in each section.

BOTTOM SECTION

Temp., F. / Comp.	300° K_b	280° K_1	266° K_2	257° K_3	249° K_4	243° K_5	233° K_6
C_1	21.7	20.5	19.5	19.0	18.54	18.2	17.30
C_2	6.4	5.8	5.47	5.24	5.05	4.91	4.63
C_3	2.7	2.4	2.24	2.14	2.06	2.00	1.88
C_4	1.45	1.3	1.21	1.15	1.10	1.064	0.996
C_5	0.82	0.72	0.65	0.602	0.583	0.542	0.494
C_6	0.49	0.40	0.359	0.332	0.321	0.292	0.263

Comp.	225° K_7	215° K_8	189° K_9	$\bar{S}_1$	$\bar{S}_2$	$\bar{S}_3$	$\bar{S}_4$
C_1	16.85	16.05	12.86	13.88	13.20	12.86	12.55
C_2	4.45	4.18	3.08	3.927	3.703	3.547	3.419
C_3	1.80	1.69	1.37	1.625	1.516	1.449	1.395
C_4	0.95	0.88	0.65	.880	.819	.7786	.7447
C_5	0.465	0.423	0.308	.4874	.4401	.4076	.3947
C_6	0.243	0.217	0.145	.2708	.2430	.2248	.2173

Comp.	$\bar{S}_5$	$\bar{S}_6$	$\bar{S}_7$	$\bar{S}_8$	$\bar{S}_9$	$\bar{S}_9\bar{S}_8$	$\bar{S}_9\bar{S}_8\bar{S}_7$
C_1	12.32	11.71	11.41	10.87	15.55	169.03	1928.6
C_2	3.324	3.135	3.013	2.830	3.724	10.539	31.754
C_3	1.354	1.273	1.219	1.144	1.656	1.8945	2.3094
C_4	.7203	.6743	.6432	.5958	.7859	.4682	.3011
C_5	.3669	.3344	.3148	.2864	.3724	.1067	.03359
C_6	.1977	.1781	.1645	.1469	.1753	.02575	.00424

Assumed Tray Temperatures and Vapor-Liquid Loadings

TRAY	Temperatures	V	L	V L
Condenser	63	59.9	90	
6	105	149.9	90	1.666
5	119	149.9	90	1.666
4	123	149.9	90	1.666
3	132	149.9	90	1.666
2	144	149.9	90	1.666
1	160	149.9	90	1.666
9 (Feed)	189	149.9	124	1.209
8	215	83.9	124	.677
7	225	83.9	124	.677
6	233	83.9	124	.677
5	243	83.9	124	.677
4	249	83.9	124	.677
3	257	83.9	124	.677
2	266	83.9	124	.677
1	280	83.9	124	.677
Reboiler	300	83.9	40.1	2.092

These assumed vapor-liquid rates and tray temperatures are the same as given in the Edmister problem with the exception that the feed tray temperature has been assumed as 189° rather than 205°.

Comp.	$\bar{S}_9 \ldots \bar{S}_6$	$\bar{S}_9 \ldots \bar{S}_5$	$\bar{S}_9 \ldots \bar{S}_4$	$\bar{S}_9 \ldots \bar{S}_3$	$\bar{S}_9 \ldots \bar{S}_2$	$\frac{\overline{\phi_2 S} = \bar{S}_9 \ldots \bar{S}_1}{\bar{S}_9 \ldots \bar{S}_1}$	$\overline{\phi_1 S - 1}$
C_1	22584	278235	3,491,850	$>10^6$	$>10^6$	$>10^6$	$>10^6$
C_2	99.549	330.90	1131.3	4012.7	14,859	58,351	78,830
C_3	2.9399	3.9806	5.5529	8.0462	12.198	19.822	58.400
C_4	.20303	.14624	.10890	.08479	.06944	.06111	2.2287
C_5	.01123	.00412	.00163	.00066	.00029	.00014	.5308
C_6	.00076	.00015	.00003	.00001	.00000	.00000	.2062

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Try C = 1.0 Using Eq. (12).

Comp.	$\frac{\bar{V}_b K_b}{B}$	$\frac{\bar{V}_b K_b \phi_2 S}{B}$	(S)	(R)/(S)	f	b
C_1	45.40	$>10^6$	$>10^6$	$<10^{-6}$	26.0	26.000
C_2	13.39	781,320	860,150	1.47×10^{-6}	9.0	9.000
C_3	5.648	111.95	170.35	.01470	25.0	24.638
C_4	3.033	.1853	2.4140	53.090	17.0	0.314
C_5	1.715	.0002	0.5310	152,020	11.0	0.000
C_6	1.025	.0000	0.2062	$>10^6$	12.0	0.000
					100.0	59.952

Try C = 1.081 Rounding off to 1 decimal.

Comp.	C(R)/(S)	d	d	b
C_1	$<10^{-6}$	26.000	26.0	0.0
C_2	1.59×10^{-6}	9.000	9.0	0.0
C_3	.01589	24.609	24.6	0.4
C_4	57.390	0.291	0.3	16.7
C_5	164,334	0.000	0.0	11.0
C_6	$>10^6$	0.000	0.0	12.0
		59.900	59.9	40.1

It will be necessary to confirm the assumed temperature gradient by a tray to tray analysis since this solution is based on the equilibrium tray concept and an assumed 189° feed tray temperature. (It will not be necessary to check vapor-liquid loadings since equi-molal overflow has been assumed for this illustration). The first step will be to calculate the concentration of C_1, C_2 components below the feed tray using equations (16) and (17) and the concentration of C_4, C_5 components above the feed tray using equations (18) and (19). This calculation is as follows:

1. Light Components Below Feed Tray

$$\bar{v}_9 = d\sqrt{C}\,(R) \qquad \sqrt{C} = \sqrt{1.081} = 1.039$$

Comp.	$\bar{v}_9$	$\bar{S}_9$	$\bar{l}_9 = \bar{v}_8$	$\bar{S}_8$	$\bar{l}_8 = \bar{v}_7$	$\bar{S}_7$	$\bar{l}_7 = \bar{v}_6$	$\bar{S}_6$	$\bar{l}_6 = \bar{v}_5$
C_1	28.41	15.55	1.83	10.87	0.17	11.41	0.015	.....	.....
C_2	11.84	3.724	3.18	2.830	1.12	3.013	0.37	3.135	0.12

2. Heavy Components Above Feed Tray

$$v_0 = \frac{b\,(S)}{\sqrt{C}}$$

Comp.	$v_0 = l_1$	S_1	$v_1 = l_2$	S_2	$v_2 = l_3$	S_3	$v_3 = l_4$	S_4	$v_4 = l_5$
C_5	5.62	0.400	2.25	0.3257	0.73	0.2766	0.20	0.2391	0.048
C_6	2.38	0.175	0.42	0.1351	0.056	.....	.....	.....	.....

Enriching Section Tray to Tray Calculations

Comp.	d	$K^{63°}$	d/K	l_4	v_6	$K^{105°}$	v_6/K	l_6
C_1	26.0	7.7	3.38	5.03	31.03	9.80	3.17	1.89
C_2	9.0	1.5	6.00	8.93	17.93	2.05	8.75	5.22
C_3	24.6	0.5	49.20	73.24	97.84	0.76	128.74	76.73
C_4	0.3	0.16	1.88	2.80	3.10	0.30	10.33	6.16
	59.9		60.46	90.00	149.90		150.99	90.00

Comp.	v_5	$K^{119°}$	v_5/K	l_5	v_4	$K^{123°}$	v_4/K	l_4
C_1	27.89	10.2	2.73	1.66	27.66	10.5	2.63	1.57
C_2	14.22	2.24	6.35	3.85	12.85	2.29	5.61	3.35
C_3	101.33	0.84	120.63	73.23	97.83	0.88	111.16	66.40
C_4	6.46	0.35	18.46	11.21	11.51	0.372	30.94	18.48
C_5				0.048	0.048	0.1435	0.33	0.20
	149.90		148.17	90.00	149.90		150.67	90.00

Comp.	v_3	$K^{132°}$	v_3/K	l_3	v_2	$K^{144°}$	v_2/K	l_2
C_1	27.57	10.93	2.52	1.52	27.52	11.44	2.41	1.46
C_2	12.35	2.45	5.04	3.03	12.03	2.63	4.57	2.77
C_3	91.00	0.95	95.79	57.59	82.19	1.040	79.03	47.97
C_4	18.87	0.417	45.04	27.08	27.38	0.473	57.89	35.14
C_5	0.20	0.166	1.20	0.72	0.72	0.1955	3.68	2.24
C_6				0.056	0.056	0.0811	0.69	0.42
	149.90		149.59	90.00	149.90		148.27	90.00

Comp.	v_1	$K^{160°}$	v_1/K	l_1	v_0
C_1	27.46	12.3	2.23	1.38	27.38
C_2	11.77	2.94	4.00	2.47	11.47
C_3	72.57	1.17	62.03	38.33	62.93
C_4	35.44	0.553	64.09	39.59	39.89
C_5	2.24	0.24	9.33	5.76	5.76
C_6	0.42	0.105	4.00	2.47	2.47
	149.90		145.68	90.00	149.90

$T_1 = 163°$

Stripping Section Tray to Tray Calculations

Comp.	b	$K^{300°}$	Kb	v_b	$\bar{l}_1$	$K^{280°}$	$K\bar{l}_1$	$\bar{v}_1$
C_3	0.4	2.7	1.08	2.25	2.65	2.40	6.36	4.27
C_4	16.7	1.45	24.22	50.55	67.25	1.30	87.43	58.69
C_5	11.0	0.82	9.02	18.83	29.83	0.72	21.48	14.42
C_6	12.0	0.49	5.88	12.27	24.27	0.40	9.71	6.52
	40.1		40.20	83.90	124.00		124.98	83.90

Comp.	$\bar{l}_2$	$K^{266°}$	$K\bar{l}_2$	$\bar{v}_2$	$\bar{l}_3$	$K^{257°}$	$K\bar{l}_3$	$\bar{v}_3$
C_3	4.67	2.24	10.46	7.03	7.43	2.14	15.90	10.72
C_4	75.39	1.21	91.22	61.30	78.00	1.15	89.70	60.50
C_5	25.42	0.65	16.52	11.10	22.10	0.602	13.30	8.97
C_6	18.42	0.359	6.65	4.47	16.47	0.332	5.47	3.69
	124.00		124.85	83.90	124.00		124.37	83.90

Comp.	$\bar{l}_4$	$K^{249°}$	$K\bar{l}_4$	$\bar{v}_4$	$\bar{l}_5$	$K^{243°}$	$K\bar{l}_5$	$\bar{v}_5$
C_2	.....	.....	.....	.....	.....	.....	.....	0.12
C_3	11.12	2.06	22.91	15.44	15.84	2.00	31.68	21.22
C_4	77.20	1.10	84.92	57.22	73.92	1.064	78.65	52.70
C_5	19.97	0.583	11.64	7.84	18.84	0.542	10.21	6.84
C_6	15.69	0.321	5.04	3.40	15.40	0.292	4.50	3.02
	124.00		124.51	83.90	124.00		125.04	83.90

Comp.	$\bar{l}_6$	$K^{233°}$	$K\bar{l}_6$	$\bar{v}_6$	$\bar{l}_7$	$K^{225°}$	$K\bar{l}_7$	$\bar{v}_7$
C_1	.....	.....	.....	0.015	0.015	16.85	0.25	0.17
C_2	0.12	4.63	0.56	0.38	0.38	4.45	1.69	1.14
C_3	21.62	1.88	40.65	27.70	28.10	1.80	50.58	34.05
C_4	69.40	0.996	69.12	47.11	63.81	0.95	60.62	40.81
C_5	17.84	0.494	8.81	6.00	17.00	0.465	7.91	5.33
C_6	15.02	0.263	3.95	2.69	14.69	0.243	3.57	2.40
	124.00		123.09	83.90	124.00		124.62	83.90

Comp.	$\bar{l}_8$	$K^{215°}$	$K\bar{l}_8$	$\bar{v}_8$	$\bar{l}_9$	$K^{189°}$	$K\bar{l}_9$	$\bar{v}_9$
C_1	0.17	16.05	2.73	1.81	1.81	12.86	23.28	27.68
C_2	1.14	4.18	4.77	3.17	3.17	3.08	9.76	11.60
C_3	34.45	1.69	58.22	38.65	39.05	1.37	53.50	63.60
C_4	57.51	0.88	50.61	33.61	50.31	0.65	32.70	38.88
C_5	16.33	0.423	6.91	4.59	15.59	0.308	4.80	5.71
C_6	14.40	0.217	3.12	2.07	14.07	0.145	2.04	2.43
	124.00		126.36	83.90	124.00		126.08	149.90

$\bar{T}_8 = 212°$ $\bar{T}_9 = 187°$

A comparison of the top-down feed tray vapor, v_o, and the bottom-up feed tray vapor, $\bar{v}_9$, indicates that a satisfactory feed plate match has been obtained and that the tray to tray solution is satisfactory. The product compositions obtained in this example are in agreement with both the Lewis-Matheson and Thiele-Geddes solutions as can be seen by referring to Edmister,[1] examples (27) and (28). This same answer has been obtained although there is considerable difference in the feed plate temperature as calculated by this method (187°) using an equilibrium tray concept and by Edmister (205°) using the flashed feed tray concept. This is to be expected, however, since the higher $\frac{V}{L}$ on the feed tray using the equilibrium tray concept has been compensated by a lower temperature and lower K's so as to give approximately the same separation as would be obtained with the flashed feed tray concept.

In the actual operation of a tower, we would not expect the vapor in a partially vaporized feed to totally disengage from the liquid on passing through the feed nozzle on a tower. Neither would we expect the vapor to be totally entrained in the liquid until equilibrium on the tray was obtained. A feed tray situation intermediate between total disengagement of feed vapor and total retention of feed vapor is probably more correct. Since the results of the example problem indicate little difference in the final answer by either feed tray concept, it appears justifiable to use the simpler equilibrium feed tray concept without further modification.

If it had been desired to calculate the correct vapor-liquid tray loadings rather than assume equi-molal overflow, it would be necessary to make heat balances on every tray. The tray temperatures and vapor-liquid loadings would then be plotted, smoothed and used in a solution of the fractionation equations. The procedure would be continued until a satisfactory tray to tray solution was obtained.

A great advantage of the proposed method is the ability to develop fractionation equations to handle almost any conceivable fractionation arrangement. Tabulated in the appendix are fractionation equations for numerous arrangements. With a little familiarity with the equations, the designer can easily develop equations for other tower arrangements.

Included are equations for an absorber, a stripper, and a gas scrubber. The equations are particularly advantageous for these towers since the equations are valid whether absorption or stripping be the mechanism in the tower.

Lean oil absorption and steam stripping towers present a slightly different problem than fractionating towers because of the low efficiencies involved. There can be a choice of methods for calculating tray temperatures and vapor-liquid profiles. One choice is to use the equations of Horton Franklin as described by Edmister[1] whereby it is assumed that

$$(22)\quad \left(\frac{V_n}{V_o}\right)^{1/n} = \frac{V_i}{V_{i-1}} \text{ and}$$

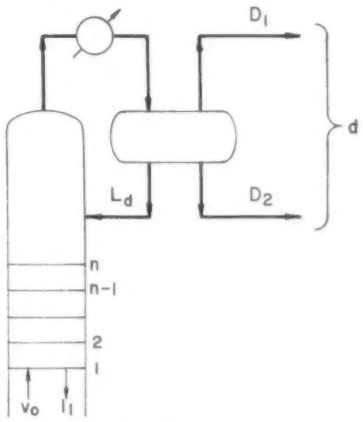
$$(23)\quad \frac{T_1 - T_i}{T_1 - T_{n+1}} = \frac{V_o - V_{i-1}}{V_o - V_n} \quad \text{(with trays numbered from the bottom up)}$$

Using equations (22) and (23), the fractionation factor, *S*, can be calculated for the top, bottom and intermediate trays and the series expressions (equations 3 and 4) can then be evaluated. If the change in tray temperatures and tray loadings is not too great, alternately, the average factor, S avg. can be estimated and equations (20) and (21) can be used instead of the series expressions. The second choice is to verify tray temperatures and the vapor-liquid profile by the tray to tray calculation procedure previously described. However, we are faced with the problem that tray efficiencies are low and are not the same for each component. An average over-all tray efficiency thus does not apply too well to components that represent extremes in the feed. Since these components are critical in determining tray temperatures, the tray temperatures calculated from equilibrium considerations and using an average tray efficiency may not correspond very well with those in an actual operating tower. The tray to tray calculation procedure may give inaccurate results in this situation and therefore, it appears justifiable to use a short cut procedure such as the Horton-Franklin equation to obtain temperatures and vapor-liquid profiles. For higher efficiency towers such as refluxed or reboiled absorbers and strippers, the tray to tray calculation procedure should be used.

The calculation procedure herein described is valuable because of the ability to handle complex tower arrangements and the rapid convergence to a final solution. The method is valuable for computer solution of distillation problems for the same reasons.

APPENDIX

Fractionation Equations



1. Top Section with Liquid and Vapor Overhead Products.

$$(24)\quad \frac{v_o}{d} = \frac{\phi_1 S}{\phi_2 S} + \frac{L_d}{(D_2 + D_1 K_d)(\phi_2 S)}$$

If D_1 or D_2 is zero, equation 24 simplifies to all liquid or all vapor overhead product respectively.

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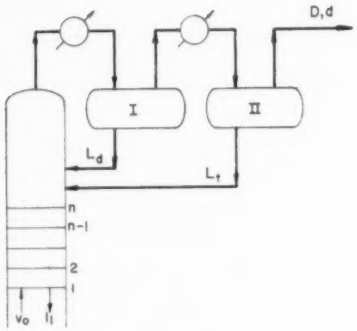
2. Top Section with Two Overhead Condenser Stages-Vapor Product.



$$(25)\quad \frac{v_o}{d} = \left(1 + \frac{L_t}{DK_t}\right)\left(\frac{\phi_1 S}{\phi_2 S} + \frac{L_d}{K_d\,(L_t + D)\,(\phi_2 S)}\right)$$

Note: K_d determined at temperature in drum I
K_t determined at temperature in drum II

3. Bottom Section with Reboiler. As shown previously in Section IIB, the fractionation equation is as follows:

$$(9)\quad \frac{\bar{v}_n}{b} = \frac{\bar{V}_b K_b}{B}\overline{\phi_2 S} + \overline{\phi_1 S} - 1$$

4. Stripper or Stripping Section of a Fractionator.

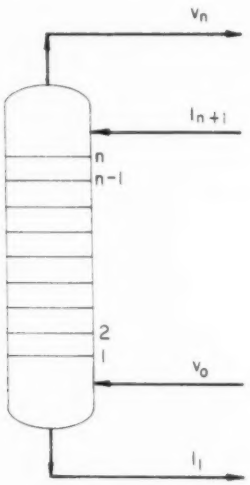
$$(26)\quad v_n = l_1\,(\phi_1 S - 1) - v_o\,(\phi_1 S - \phi_2 S - 1) \text{ or}$$
$$l_1\,(\phi_1 S) = v_o\,(\phi_1 S - \phi_2 S) + l_{n+1}$$

If V_o is essentially inert (such as steam) and does not contain components that appear in the feed or bottoms liquid then:

$$(27)\quad \frac{v_n}{l_1} = \phi_1 S - 1$$

Or

$$l_1 = \frac{l_{n+1}}{\phi_1 S}$$



Note that in evaluating the fractionation factor $S = \frac{KV}{L}$ when inert vapors are present, that K is evaluated at the total pressure of the system and the moles of inert vapors are included in the quantity, *V*.

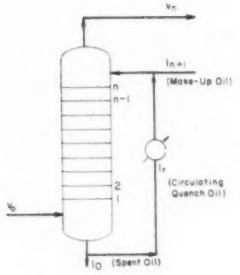
5. Absorber or Enriching Section of a Fractionator. (See 4 for Figure.)

$$(28)\quad v_o\,(\phi_2 S) = v_n\,(\phi_1 S) - l_{n+1}\,(\phi_1 S - 1)$$

If none of the components of l_{n+1} appear in v_n or v_o then:

$$(29)\quad \frac{v_o}{v_n} = \frac{\phi_1 S}{\phi_2 S}$$

6. Gas Scrubber.



$$(30)\quad \text{Let } \Theta = \frac{l_o}{l_r}$$

$$(31)\quad l_r = \frac{v_o\,(\phi_1 S - \phi_2 S) + l_{n+1}}{(1 + \Theta)\,(\phi_1 S) - 1}$$

By trial and error determine the value of Θ that results in the desired quantity of L_r, where $L_r = \Sigma\, l_r$.

7. Fractionation Towers with Side Reboilers, Side Condensers or Inert Stripping Vapor.

These modifications are taken care of simply by adjusting the fractionation factor, $S = \frac{KV}{L}$, for changes in tray temperatures and vapor-liquid loadings due to the addition or subtraction of vapor by side reboilers, condensers or inert stripping vapor. In the case of side reboilers or condensers, the effect of vapor-liquid separation at the exit of the reboiler or condenser return line is neglected by this procedure. However, the effect of the additional separation is minor and can justifiably be neglected.

Nomenclature

b	Moles of component in bottoms product
B	total moles of bottoms product
C	correction factor for simultaneously solving fractionation equations
d	moles of component in distillate product
f	moles of component in feed
F	total moles of feed
K	equilibrium constant = y/x
l	moles of a component in liquid downflow
L	total moles of liquid downflow
n	number of theoretical trays (numbered from bottom to top) in a section
(R)	$= v_o/d$ in top section of a conventional fractionator
(S)	$= v_n/b$ in bottom section of a conventional fractionator
S	fractionator factor = KV/L
T	temperature
v	moles of a component in vapor flow
V	total moles of vapor upflow
x	mole fraction of component in liquid phase
y	mole fraction of component in vapor phase
z	mole fraction of component in feed
$\phi_1 S$	$= S_1 S_2 S_3 \ldots S_n + S_2 S_3 \ldots S_n + S_3 S_4 \ldots S_n + \ldots + S_n + 1$
$\phi_2 S$	$= S_1 S_2 S_3 \ldots S_n$
Σ	indicates summation of:

Superscripts

—	component or tray in the bottom section of a conventional fractionator

Subscripts

o,1,2	component or trays o, 1, 2, etc.
i	i^{th} component or tray
n	top tray in a section
b	at bottoms product condition
d	at distillate product condition
f	at feed composition condition

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Estimate Gas or Liquid Viscosity Data

Viscosity is a property which appears in many engineering problems. Here are some methods of correlating and estimating it

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VISCOSITY IS a property which appears in all fluid flow, and heat and mass transfer correlations. It is usually a property which must be known as accurately as possible. Here are some methods of correlating and estimating these data.

If the viscosity of a vapor or liquid is known at two different temperatures, interpolation or extrapolation to other temperatures is best carried out using the Othmer viscosity plots described in Sections 2a and 3a.

Vapor viscosities at lower pressures may be estimated by the nomograph of Section 2c with sufficient accuracy for most engineering purposes. This chart holds for mixtures although the equations of Section 2d iii give better accuracy. For estimating viscosities of gases at very high pressures, the generalized correlation described in Section 2b should be used.

Where possible, liquid viscosities should be measured in the laboratory. When treating new members of a homologous series, the methods described in Sections 3b and 3c will permit extrapolation of data. In estimating viscosities of liquids, all methods described in 3d should be used and an average value taken.

1. CORRELATING TOOLS

In general the correlating methods discussed in this article are empirical ones. However, a relationship between structure and viscosity has been observed by several workers[18,33,36] leading to attempts to devise correlating groups similar to the parachor. The most successful of these to date is the rheochor using the table of atomic and structural contributions.

TABLE 1—Atomic and Structural Rheochor Values of Friend and Hargreaves[5]

Carbon	12.8	Hydrogen	C-H	5.5
Chlorine	27.3		C-OH	10.0
Bromine	35.8		H-Cl	9.7
COO-group	36.0		H-Br	12.6
Phenyl group	100.7		H-I	15.0
Methylene group	23.8	Oxygen in ether		10.0
CN	33.0	Nitrogen		6.6
NH	13.6			

Viscosity Is Based On These Definitions

The *absolute viscosity*, μ, is the proportionality constant relating the shearing force τ required to move two imaginary parallel surfaces in fluid separated distance dx at a relative velocity dv:

$$\tau = \mu \frac{dv}{dx} \qquad (1)$$

When the force is one dyne per square centimeter, the velocity is one centimeter per second, and the surfaces are separated a distance of one centimeter, the proportionality constant is defined as 1 poise. For liquids the more common unit is a centipoise (0.01 poise) and for gases a micropoise (10^{-6} poise or 10^{-4} centipoise).

In engineering correlations involving dimensionless groups, the units of viscosity are usually pounds mass per hour per foot. To convert centipoise to the engineering unit, centipoise should be multiplied by 2.42.

The *kinematic viscosity* is the absolute viscosity divided by the density.

$$\nu = \frac{\mu}{d}$$

when the absolute viscosity is in poises and the density in grams per cubic centimeter, the units of kinematic viscosity are stokes.

The *fluidity* is the reciprocal of the absolute viscosity. When the absolute viscosity is in poises, the units of fluidity are *rhes*. The symbol for fluidity is ϕ.

The *critical viscosity* is the viscosity of a compound at the critical temperature and pressure.

The *reduced viscosity* as used in this article is the ratio of the absolute viscosity at any condition compared to the critical viscosity. This is not to be confused with the reduced viscosity used in studying polymer solutions.

The *relative viscosity* is the ratio of the viscosity of a solution to that of the pure water at 20°C.

The *rheochor* is an empirical viscosity function similar to the parachor relating the constitution of a compound to its viscosity

$$[R] = \frac{M(\mu'')^{1/4}}{D + 2d} \qquad (2)$$

Here D and d are the liquid and vapor densities in grams per cubic centimeter; D, d, and μ'' all refer to the normal boiling point.

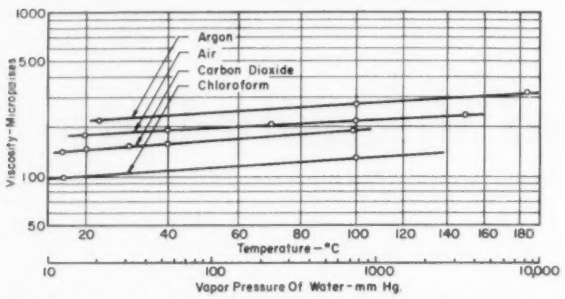

FIGURE 1—An Othmer plot relates viscosity to the vapor pressure of a second substance, usually water. The vapor pressure of the reference substance defines the temperature scale.

a. Rheochor values of Friend and Hargreaves[5]: The atomic and structural contributions devised by these authors are shown in Table 1.

Example 1. The rheochor of methyl ethyl ketone may be calculated as follows:

$C_2H_5-C(=O)-CH_3$	1 COO group	(1) (36.0) = 36.0
	3 Carbon	(3) (12.8) = 38.4
	8 Hydrogen	(8) (5.5) = 44.0
	—1 Oxygen (assumed similar to O in ether)	(—1) (10.0) = —10.0
		108.4

The experimental value is 108.4, in agreement with the value as calculated above.

For compounds which can be tested by the values of Table 1, predicted rheochor values give excellent agreement with observed values. It should be pointed out that the molecular volume term M/D is also additive and may obscure the significance of the viscosity term.

b. Souders' viscosity-constitution constant: Souders[33] observed a relationship between the viscosity and density of liquids and proposed a term I which depends on the constitution

$$\log (\log \mu'') = \frac{I}{M} d - 2.9 \qquad (3)$$

For any compound, the viscosity-constitution constant "I" may be calculated from the values of Table 2.

Example 2. For ethyl butyrate the viscosity-constitution constant may be estimated as follows:

$CH_3-CH_2-CH_2-C(=O)-O-C_2H_5$

2 CH_3 group	(2) (58.3)	= 116.6
3 CH_2 group	(3) (55.6)	= 166.8
1 COO group	(1) (90.0)	= 90.0
		I = 373.4

This value will be used in Example 17.

2. VAPOR VISCOSITY

The viscosities of vapors are generally difficult to measure in the laboratory. Fortunately, reliable methods exist for extrapolating data, for estimating vapor viscosities under a wide range of conditions and for obtaining viscosities of vapor mixtures.

a. Othmer viscosity plot: If the viscosities of a vapor are known at two different temperatures and at the same pressure, the Othmer viscosity plot forms a convenient straight-line plot for interpolation or extrapolation[29].

Similar to the Othmer vapor pressure plot, this viscosity plot is a graph of the viscosity of the vapor against the vapor pressure of a reference substance on logarithmic paper, each point representing the same temperature. Again a superimposed temperature scale can be drawn in based on the reference vapor pressure scale. Water forms the most useful reference substance although others can be used.

Example 3. Figure 1 shows the viscosities of several vapors on an Othmer plot. Straight lines are obtained over a wide temperature range. These lines are all for one atmospheric pressure. The effect of pressure is small except at very high (or very small) pressures. At higher pressures, isobaric data will plot similar straight lines.

Isobaric data for mixtures of gases are also straight on these plots. Illustrations of high-pressure data and of data for mixtures are given by Othmer.[29]

In general, good straight lines are obtained except in the region of the critical temperatures of the substance plotted or the reference substance and close to the condensing temperature of the vapor.

b. Method of Uyehara and Watson: This method[39] depends on an empirical plot of reduced viscosity μ_r as a function of reduced temperature and reduced pressure. When the empirical value of the critical viscosity is not available in literature, it may be estimated by either of the following equations.[28, 39]

$$\mu'_c = 7.70 \sqrt{M} (p_c)^{2/3} / T_c^{1/6}$$

or

$$\mu'_c = 61.6 \sqrt{MT_c} / v_c^{2/3}$$

The generalized correlation permits estimation of a vapor viscosity at any temperature and pressure if the critical conditions are known.

Example 4. To illustrate the use of the method, estimate the viscosity of acetylene at 0 C. and 1 atmosphere pressure. The critical temperature and pressure of acetylene are 309.2 K and 62 atmospheres. Hence

$$P_r = \frac{273.2}{309.2} = 0.884$$

$$p_r = \frac{1}{62.0} = 0.0161$$

TABLE 2—Souders' Atomic and Structural Viscosity Constants I

ATOMIC CONTRIBUTIONS			
Carbon	50.2	Nitrogen	37
Hydrogen	2.7	Chlorine	60
Oxygen	29.7	Bromine	79
Methylene group	55.6	Iodine	110
Hydroxyl group	57.1	COOH group	104.4
COO-group	90.0	Nitro-group	80
STRUCTURAL CONTRIBUTIONS			
Double bond	—15.5	RCHO	+16
$R_2CH-CHR_2$	+ 8	$RCCH_3$ (O)	+ 5
CR_4	+13		
5-membered carbon ring	—24		
6-membered carbon ring	—21		
Side group on 6-membered carbon ring			
molecular weight less than 17	— 9		
molecular weight more than 16	—17		
ortho- and para-	+ 3		
meta-	+ 1		
$-CH=CHCH_2X$	+ 4		
R_2CHX	+ 6		

(where X is a negative group)

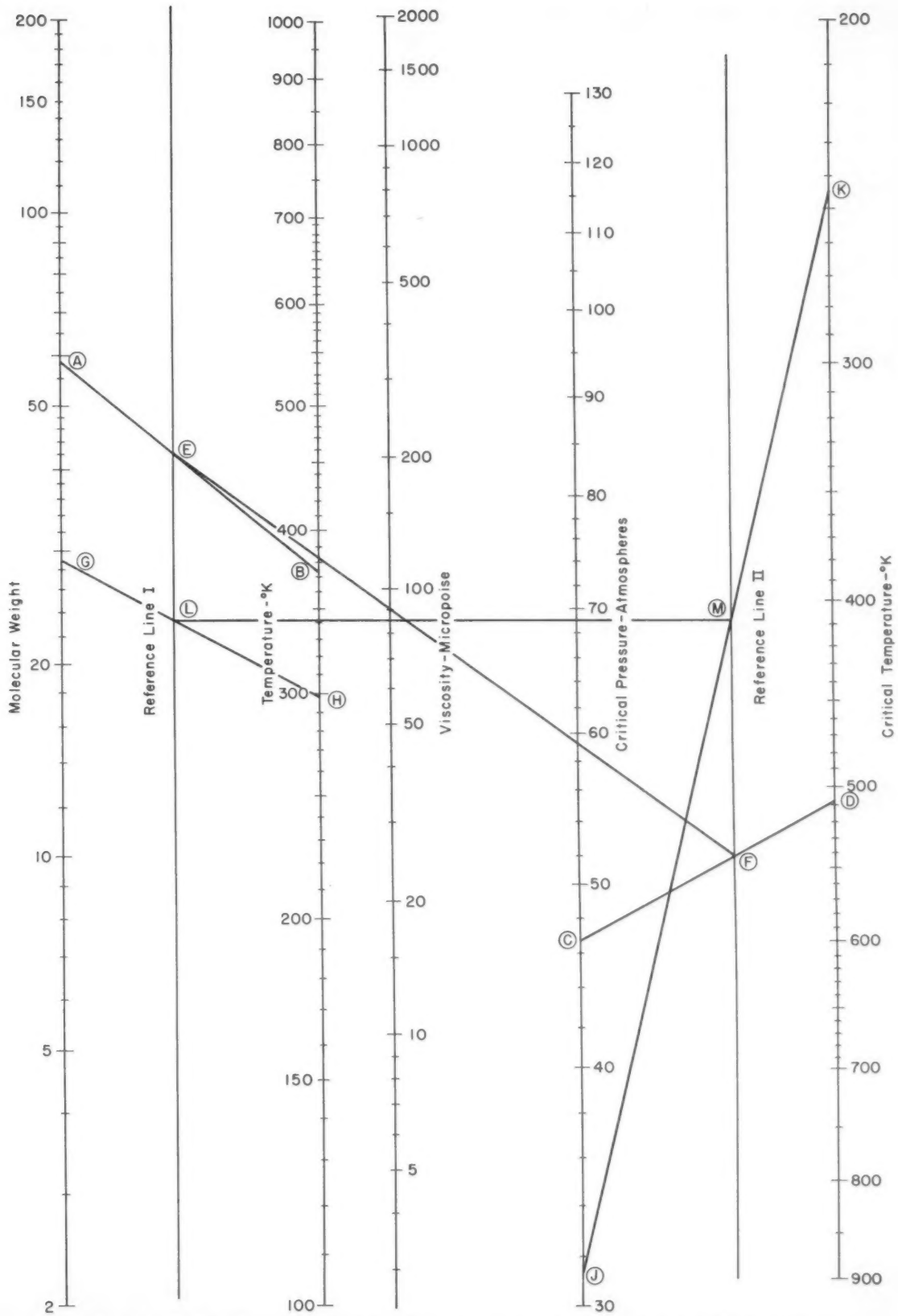

FIGURE 2—The line chart gives a rapid solution to the equation of viscosity referred to critical conditions.

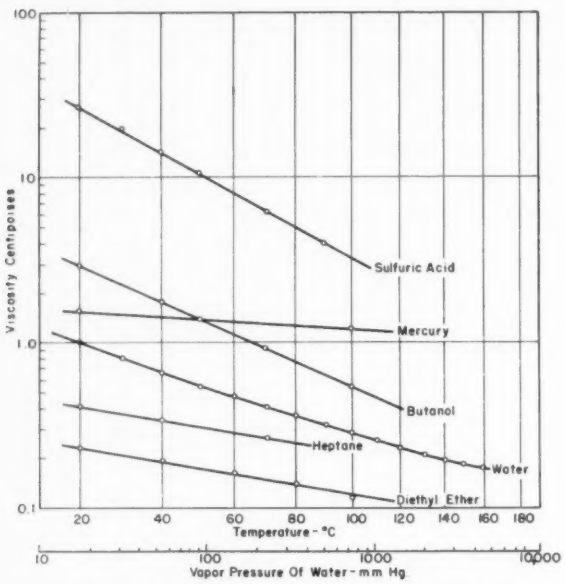

FIGURE 3—The Othmer plot provides an excellent method of extrapolating data.

The critical viscosity was calculated by the above equations to be 237 micropoises. From Figure in the reference,[39] the reduced viscosity corresponding to the above reduced temperature and pressure is 0.39.

Therefore, $\mu' = (237)(0.39) = 94.5$ micropoise; the experimental value[21] is 93.5 micropoise.

If the viscosity of a vapor is known at one temperature and pressure, the chart may be used to estimate the critical viscosity. This is illustrated as follows:

Example 5. The viscosity of chlorine at 250 C. and 1 atmosphere is given[21] as 227.6 micropoises. To find the critical viscosity at the given conditions,

$$T_r = \frac{523.2}{417} = 1.255$$

$$p_r = \frac{1}{76.1} = 0.0132$$

From Figure,[39] $\mu_r = 0.55$

Hence $\mu_c' = \frac{227.6}{0.55} = 414$ micropoises

This is close to the experimental value of 420 micropoises.

c. **Nomograph:** In Figure of reference,[39] it may be observed that for pressure below the critical pressure, that is, for values of p_r less than unity, the effect of pressure on vapor viscosities is small. For low pressure data, the following equation which follows from this observation may be used to obtain vapor viscosities[22]:

$$\mu' = 4.53\, M^{1/2} \left(\frac{p_c}{T_c}\right)^{2/3} T^{0.782} \qquad (4)$$

Figure 2 is a nomograph based on this equation; this permits rapid estimation of the viscosity of a vapor at any temperature at pressures lower than critical, having available the critical pressure and temperature and the molecular weight.

Example 6. The lines AB, CD, and EF on Figure 2 are a sample calculation of the viscosity of acetone vapor at 100C. and at atmospheric pressure. Acetone has a molecular weight of 58.1, a critical temperature of 509 K. and a critical pressure of 46.6 atmospheres. The value read from the chart is 90 micropoises compared to a tabulated value of 94.3 micropoises.

The accuracy of vapor viscosities calculated from either method 2b and Figure 2 may be classed as good. For water, methanol, hydrogen, helium, neon, and bromine the results are fair. Due to the insufficient amount of empirical data, the applicabilities of Figure 2 and method 2b to high temperature viscosities cannot be well tested.

d. Vapor mixtures: The viscosities of vapor mixtures cannot be calculated by simple weighting of the viscosities of the components, especially for mixtures containing hydrogen. The following methods are recommended:

(i). Vapor viscosity nomograph: Figure 2 may be used to yield viscosities of vapor mixtures if the molal average molecular weight and the pseudocritical temperature and pressure are used.

Example 7. The use of this graph for vapor mixtures is illustrated by the calculation of the viscosity of a mixture of 37 percent hydrogen in propane at 25 C. and at atmospheric pressure. For this mixture

$$M' = (0.37)(2) + (0.63)(44) = 28.9$$
$$T'_c = (0.37)(33.2) + (0.63)(370) = 245.3°K$$
$$p'_c = (0.37)(12.8) + (0.63)(42) = 31.2atm.$$

By the line GH, JK, LM on Figure 2 the calculated viscosity is 85 micropoises. The observed viscosity is 87.4 micropoises.

(ii). Reduced viscosity chart: The above method is applicable only for pressures below the critical. If the viscosity of a vapor mixture is to be calculated at higher pressures, the generalized correlation of Uyehara and Watson[39] can be applied using pseudoreduced properties as in the following example:

Example 8. Example 6 is to be recalculated using the method 2b. The critical viscosities are 34.7 micropoises for hydrogen and 22.8 micropoises for propane. The pseudocritical viscosity of this mixture is therefore

$$\mu'_c = (0.37)(34.7) + (0.63)(228) = 158 \text{ micropoises.}$$

The pseudo-reduced temperature and pressure are

$$T'_r = \frac{298.2}{245.3} = 1.16$$

$$p'_r = \frac{1}{31.2} = 0.032$$

From Figure,[39] $\mu_r = 0.52$ whence

$$\mu'_m = (0.52)(158.3) = 82.4 \text{ micropoises}$$

This agrees fairly well with the observed value.

(iii). Methods of Buddenburg, Bromley and Wilke: These methods represent the most accurate treatment of vapor viscosities for mixtures. The Schudel prediction[32] of the constants in the Sutherland-Tiesen equation[35] for

TABLE 3—Thomas' Atomic and Structural K Values

Carbon	−0.462	Bromine	0.326
Iodine	.335	Double Bond	.478
Hydrogen	.249	C_6H_5	.385
Oxygen	.054	CO (ketones & esters)	.105
Chlorine	.340	CN cyanides	.381
Sulfur	.043		

the viscosities of binary gas mixtures was extended empirically by Buddenburg and Wilke[6] leading to this equation for a binary mixture.

$$\bar{\mu}_m = \frac{\bar{\mu}_1}{1 + \frac{x_2}{x_1}\left(\frac{1.385\bar{\mu}_1}{D_{12}\, d_1}\right)} + \frac{\bar{\mu}_2}{1 + \frac{x_1}{x_2}\left(\frac{1.385\bar{\mu}_2}{D_{12}\, d_2}\right)} \qquad (5)$$

where D_{12} is the diffusion coefficient in square centimeters per second. This was later modified[11] to

$$\bar{\mu}_m = \frac{\bar{\mu}_1}{1 + \frac{x_2}{x_1}\Phi_{12}} + \frac{\bar{\mu}_2}{1 + \frac{x_1}{x_2}\Phi_{21}} \qquad (6)$$

where

$$\Phi_{12} = \frac{\left[1 + \left(\frac{\bar{\mu}_1}{\bar{\mu}_2}\right)^{0.5}\left(\frac{M_2}{M_1}\right)^{0.25}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{M_1}{M_2}\right)^{0.5}} \qquad (7)$$

$$\Phi_{21} = \frac{\left[1 + \left(\frac{\bar{\mu}_2}{\bar{\mu}_1}\right)^{0.5}\left(\frac{M_1}{M_2}\right)^{0.25}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{M_2}{M_1}\right)^{0.5}} \qquad (8)$$

The latter equations have the advantage of requiring neither the diffusion coefficients nor the vapor densities.

Example 9. The viscosity of the gas mixture of Example 7 can be calculated by both equations (5) and (6) as follows.

Using Equation (5):

	Hydrogen (1)	Propane (2)
x, mole fraction	0.37	0.63
$\bar{\mu}$, poises	88.5×10^{-6}	82.5×10^{-6}
d, gm/cc	0.098×10^{-3}	2.2×10^{-3}
M	2	44
D_{12}, cm²/sec	0.297	0.297

$$\bar{\mu}_m = \frac{88.5 \times 10^{-6}}{1 + \frac{0.63}{0.37}\left[\frac{(1.385)(88.5 \times 10^{-6})}{(0.297)(0.098 \times 10^{-3})}\right]} + \frac{82.5 \times 10^{-6}}{1 + \frac{0.37}{0.63}\left[\frac{(1.385)(82.5 \times 10^{-6})}{(0.297)(2.20 \times 10^{-3})}\right]} = 85.6 \times 10^{-6} \text{ poises}$$

Using equation (6)

$$\Phi_{12} = \frac{\left[1 + \left(\frac{88.5}{82.5}\right)^{0.5}\left(\frac{44}{2}\right)^{0.25}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{2}{44}\right)^{0.5}} = 3.63$$

$$\Phi_{21} = \frac{\left[1 + \left(\frac{82.5}{88.5}\right)^{0.5}\left(\frac{2}{44}\right)^{0.25}\right]^2}{\frac{4}{\sqrt{2}}\left(1 + \frac{44}{2}\right)^{0.5}} = 0.154$$

$$\bar{\mu}_m = \frac{88.5 \times 10^{-6}}{1 + \frac{0.63}{0.37}(3.63)} + \frac{82.5 \times 10^{-6}}{1 + \frac{0.37}{0.63}(0.154)} = 87.9 \times 10^{-6} \text{ poises}$$

For multicomponent mixtures, the general form of equation to be used is

$$\bar{\mu}_m = \sum_{i=1}^{n} \frac{\mu_i}{1 + \frac{1}{x_i}\sum_{\substack{j=1 \\ j \neq i}}^{n} x_j \Phi_{ij}} \qquad (9)$$

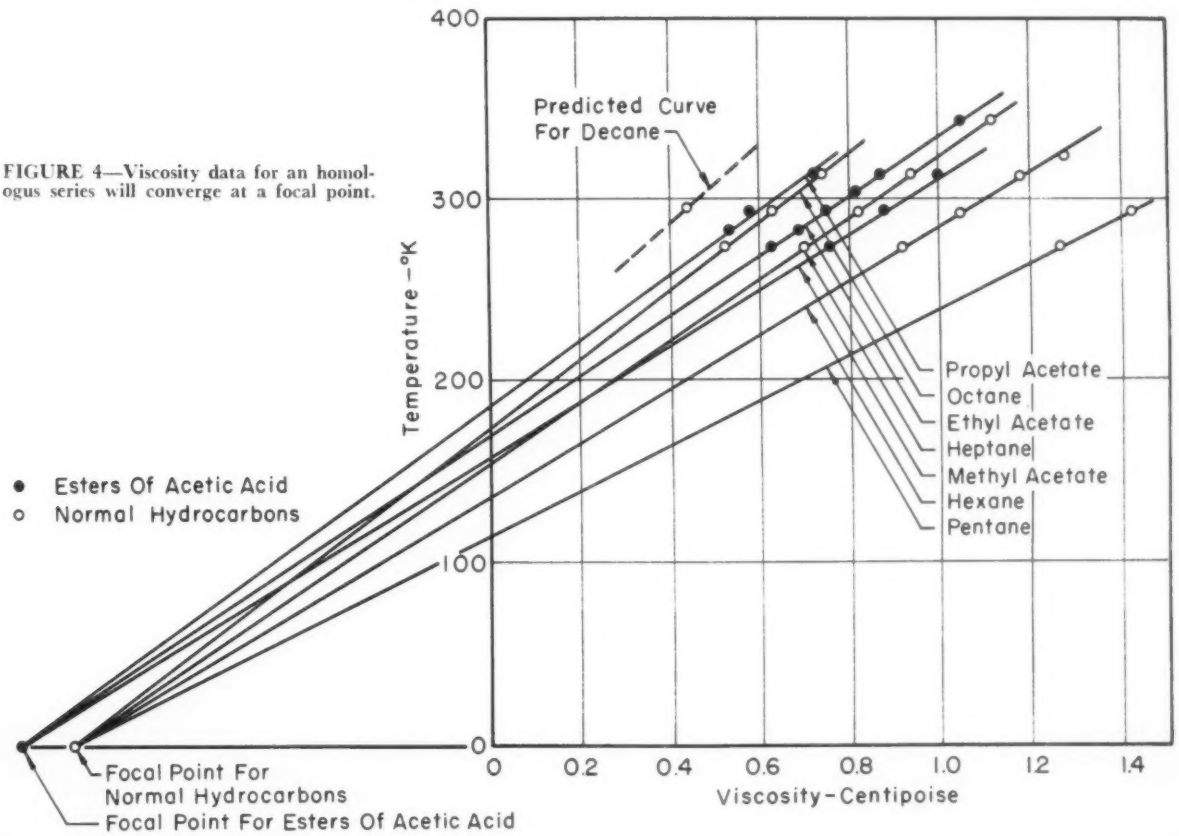

FIGURE 4—Viscosity data for an homologus series will converge at a focal point.

where

$$\Phi_{ij} = \frac{\left[1 + \left(\frac{\mu_i}{\mu_j}\right)^{0.5}\left(\frac{M_j}{M_i}\right)^{0.25}\right]^2}{\frac{4}{\sqrt{2}}\left[1 + \frac{M_i}{M_j}\right]^{0.5}} \qquad (10)$$

Applications of equations (9) and (10) for mixtures of several components is facilitated by the use of suitable tables. An example is given by Bromley and Wilke.[5]

The equations of Wilke and his coworkers give excellent results for gas mixtures. The viscosities of single vapors may be estimated with excellent results by the methods given by Bromley and Wilke.

The generalized correlation of Uyehara and Watson, and the nomograph, Figure 2, will usually give results of good accuracy for engineering calculations.

c. Variation with temperature: Equation (4) discussed in Section **c.** provides a convenient representation of the variation of vapor viscosity with temperature, that is, the viscosity varies as $T^{0.782}$ when the reduced pressure is less than one. This empirical observation is an average value based on 31 different vapors.

Example 10. Given that the viscosity of acetone vapor at 100 C. is 94.3 micropoises, estimate the viscosity at 0 C.

In accordance with the above rule,

$$\frac{\mu'_1}{\mu'_2} = \left(\frac{T_1}{T_2}\right)^{0.782} = \left(\frac{273.2}{373.2}\right)^{0.782}$$

Whence $\mu'_1 = 73.8$ micropoises. The observed value is 72.5 micropoises.

This rule will be found to be sufficiently accurate for engineering extrapolations at pressures below the critical. More detailed equations which would yield the variation of vapor viscosity with temperature may be derived from the methods of Bromley and Wilke.

f. Other treatment of vapor viscosity: It is believed that the methods discussed in Section 2 will permit calculation of almost all gas viscosities normally encountered in design. Additional references are included to facilitate a more thorough study of the subject.

A review of theoretical studies of gas viscosity is made by Brancher.[4] The most extensive text on gas properties is that by Chapman and Cowling.[8] An excellent review of the transport properties of gases and gas mixtures has been made by Hirschfelder, Bird and Spotz.[20]

Davis has prepared a nomogram[13] for obtaining the viscosities of a number of gases. Another convenient nomogram is given in Perry.[31]

Treatments of gas viscosities at high pressures similar to the method of Uyehara and Watson have been proposed by Comings and his coworkers.[11,12]

TABLE 4—Constants of the Equation $I = a\,[R_D] + b$

Series	a	b
Monohydric alcohols	12.0	16
Monocarboxylic acids	11.9	11
Esters of acetic acid	11.8	3
Aliphatic ketones	10.5	23
Ethyl esters	11.1	18
Paraffins	12.0	—20
Alkyl iodides	11.2	—47

3. LIQUID VISCOSITY

In general, viscosities of liquids are more difficult to estimate accurately than are viscosities of vapors. It is fortunate that liquid viscosity can be measured in the laboratory using very simple equipment; such as the Ostwald viscosimeter,[40] and that several means of extrapolating measurements exist.

It is recommended that laboratory values be used wherever possible and the methods discussed first will represent means of extrapolating known data.

a. The Othmer Viscosity Plot: The Othmer viscosity plot discussed in Section 2.a. for vapors and illustrated in Figure 1 may also be used to obtain straight-line plots of liquid viscosities as a function of temperature.[30] At least two points are necessary to extrapolate or interpolate data although members of a homologous series may demonstrate similar slopes.

Example 11. Figure 3 illustrates Othmer viscosity plots of several liquids. As in other Othmer plots, breaks in the viscosity plots may indicate changes in molecular structure. An example of interest is the change which occurs in water between 30 C. and 40 C.

The Othmer viscosity plot provides an excellent method of extrapolating viscosity data. If only one viscosity is known, however, and the slope is approximated from slopes of similar substances, the accuracy will be rated as fair.

b. Method of Bingham and Stookey: These workers[3] proposed that for an individual compound the fluidity may be related to the temperature by an equation of the form

$$\frac{\phi}{T} = A + B\,T \qquad (11)$$

Here A and B are characteristic constants for individual compounds. For compounds containing more than ten carbon atoms, higher terms in T may be required to fit experimental data. The constant A is usually found to be the same for all members of a series: that is, for a homologous series lines on a graph of $\frac{\phi}{T}$ plotted against T are straight and have a common intersection point at absolute zero.

Example 12 Figure 4 illustrates plots of $\frac{\phi}{T}$ against T for two homologous series, normal hydrocarbons and esters of acetic acid. Once the intersection points have been established by such a plot the viscosity line of any other member of the same series can be drawn in based on one point. In this way the curve for decane was drawn in based on one known viscosity of 0.77 centipoise at 22 C.

If the slope term B is expressed as a function of molecular weight, Equation 11 can be used to predict viscosity lines of higher members of a given series.

Example 13. Figure 5 shows a plot of the slope as a function of molecular weight for the series of normal hydrocarbons. This curve may be approximated by the equation

$$B = -0.404 + 0.011M - 0.0000281\,M^2$$

where B is the slope term of Equation 11 and M is the molecular weight of the normal hydrocarbon.

c. Reduced Viscosity Plots: Several types of reduced viscosity plots have been suggested. In proposing his original viscosity plot[30], Othmer suggested that a logarithmic plot of the reduced temperature of the com-

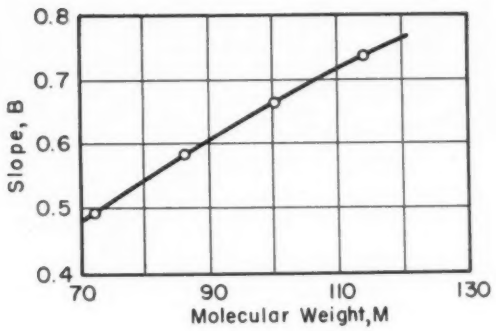

FIGURE 5—When the focal point is known for the Bingham-Stookey plot, the slope is influenced by the molecular weight.

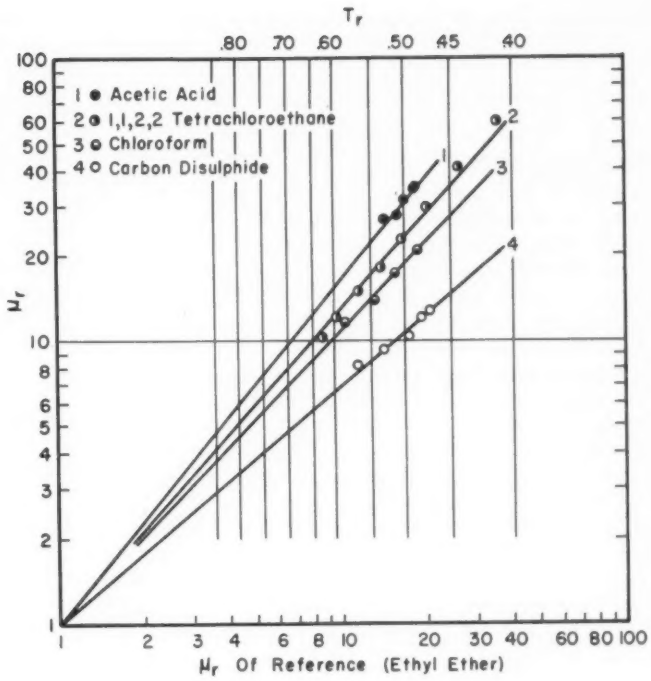

FIGURE 6—(right) When reduced viscosity of one substance is related to a second one, linear extrapolation can be made over a wider range than with the ordinary Othmer plot.

pound against the reduced temperature of a reference compound, each point corresponding to the same reduced viscosity, will yield straight lines. This method of plotting requires initial plots of reduced viscosity against reduced temperature for the reference substance.

Thomas[37] has pointed out that a large number of unassociated liquids obey the relation

$$\log \frac{\phi}{\phi_c} = 0.238 \log \frac{p}{p_c} \qquad (12)$$

That is, a logarithmic plot of reduced fluidity against the reduced vapor pressure for each point gives a common line for these liquids. This type of plot is also laborious, requiring construction of the vapor pressure curves of each compound.

A reduced viscosity plot which has been found to be fairly successful is indicated in the following example. The reduced viscosity of the compounds were plotted against the reduced viscosity of a reference compound, each point representing the same reduced temperature. Most compounds on this plot give straight lines over long temperature ranges, these lines tending to converge at 1,1.

Example 14. Figure 6 shows several compounds on a plot of reduced viscosity of the compound against the reduced viscosity of a reference compound,[23] each point corresponding to the same reduced temperature. Straight lines tending to pass through the point 1,1 were obtained for a variety of compounds. The reference substance chosen for drawing the reduced temperature scale was diethyl ether.

There are many exceptions encountered in these reduced viscosity plots. However, unassociated and unsymmetrical molecules behave fairly well. For such liquids, viscosities may be extrapolated based on one known value using Figure 6 with good accuracy.

A reduced viscosity plot such as Figure 6 usually permits linear extrapolation of viscosity data over a wider range than the ordinary Othmer viscosity plot.

d. Methods of Estimating Liquid Viscosities: Although liquid viscosity may be measured easily in the laboratory, occasionally it may be necessary to attempt to calculate a viscosity of a pure liquid. No completely satisfactory means of doing so has been devised, especially for liquids which demonstrate association and other intermolecular attractions. The following methods should be used only if necessary:

(i). Method of Thomas: The equation proposed by Thomas[37] is

$$\log (\mu'' \sqrt{v}) = C + K \left(\frac{T_c}{T} - 1 \right) \qquad (13)$$

where v is the specific volume and *C* and *K* are two empirical constants. By substituting a boundary condition of critical temperature, *C* is found to be equal to log $\mu''_c \sqrt{v_c}$. However, after examining 123 compounds, Thomas found *C* to be constant with a value of 0.0670 for non-associated liquids, and also was able to calculate suitable values of *K* based on atomic and structural components. Table 3 shows Thomas' recommended K values.

Example 15. The viscosity of ethyl butyrate at 15 C. may be estimated by Thomas' method as follows:

Structure:

$$CH_3 - CH_2 - CH_2 - \underset{\underset{O}{\|}}{C} - O - CH_2CH_3$$

5 C :	5(−0.462) =	−2.310
12 H :	12(0.249) =	2.988
O :		0.054
CO :		0.105
	K =	0.837

The density at 15 C. is 0.8842 grams per cubic centimeter. The critical temperature is 566.2 K.

$$\log\left(\mu''\sqrt{\frac{1}{0.8842}}\right) = 0.0670 + 0.837\left(\frac{566.2}{288.2} - 1\right)$$

$$\mu'' = 7.04 \text{ millipoises.}$$

The experimental value is 7.11 millipoises.

Based on 108 compounds tested by Thomas, the accuracy of this equation may be rated as good. Benzene and the alkyl halides gives poor results.

(ii). Rheochor Values: The efforts of Friend and Hargreaves to relate the structure and viscosity of liquids[18] are probably the most comprehensive and painstaking. The atomic and structural contributions proposed by them are listed in Table 1 of Section 1.a. These values are used with Equation 2 as illustrated in the following example.

Example 16. Show the use of the rheochor values of Friend and Hargreaves to estimate the viscosity of methylethylketone at the boiling point.

The rheochor for methylethylketone was calculated to be 108.4 in Example 1.

The density of methylethylketone at the boiling point is 0.740 grams per cubic centimeter. Neglecting the density of vapor, the viscosity by Equation 2 is

$$\mu'' = \left(\frac{[R]}{M}D\right)^8 = \left(\frac{108.4 \times 0.740}{72.1}\right)^8 = (1.113)^8 = 2.52 \text{ millipoises.}$$

The experimental value is 2.44 millipoises.

In this example, application of the rheochor contributions gave excellent prediction of the liquid viscosity. It is unfortunate, however, that the viscosity term in Equation 2 appears to the one-eighth power. This means that a small error in liquid density and small discrepancies in the sum of atomic contributions may result in large errors in the calculated viscosity. For this reason, the accuracy of the method should not be rated better than fair.

(iii). Method of Souders: Souders[33] observed a relationship between the viscosity, density and a constitution sensitive parameter I which has been given as Equation 3. Values of atomic and structural contributions to I were listed in Table 2.

Example 17. The Souders viscosity constitution constant for ethyl butyrate was established in Example 2 as 373.4. Estimate the viscosity at 15° C. when the density is 0.884 grams per cubic centimeter.

Using Equation 3,

$$\text{Log (log } \mu'') = \frac{I}{M}d - 2.9 = \frac{373.4}{116.6}0.884 - 2.9 = 2.825 - 2.90 = -0.075$$

Whence $\mu'' = 6.93$ millipoises.

This agrees well with the experimental value of 7.11 millipoises.

Souders tested his equation for 117 compounds, many of them at four temperatures, and found that experimental values of the viscosity constant I agreed excellently with values calculated using Table 2. In using the correlation to predict liquid viscosities, this results in good accuracy. However, for water, phenol, and some highly halogenated compounds the equation may yield only fair values of the viscosity.

Davis[14] has prepared nomograms for solving Souders' equation for the general case, where the viscosity constant is calculated from Table 2, and for individual compounds located by points on a reference scale.

The following modification of the equation has been proposed by Buehler with the inclusion of parachor value and surface tension.[7]

$$\frac{\log(\log \mu'') + 2.9}{I/[P]} = \gamma^{1/4} \qquad (14)$$

Davis[15] has prepared a nomogram for treating this equation also.

Lageman[24] has shown that I and $[R_D]$ are simply related:

$$I = a[R_D] + b \qquad (15)$$

Values of the molar refraction, $[R_D]$, may be calculated by the methods of Eisenlohr[17]. Typical values of a and b are given in Table 4.

(iv). A Proposed Line Chart: Figure 7 is a line chart suggested in private communications between the authors and J. Czerny. The equation on which the chart is based is

$$\mu = 0.0172\frac{M^{0.5}\,p_c^{0.87}}{T_c^{0.167}\,p'^{0.238}} \qquad (16)$$

Here p_c is the critical pressure in atmospheres and T_c is the critical temperature in degrees Kelvin. However, p' has the units of millimeters of mercury to facilitate the use of the equation and line chart with vapor-pressure tables such as those of Stull[34]. This equation yields the liquid viscosity at any temperature at which the vapor pressure is p millimeters of mercury.

This equation is semi-empirical but was suggested by a combination of Thomas' Equation 12 and the equation of critical viscosity by Licht and Stechert.

Example 18. Two uses of the chart are illustrated:

(a) The viscosity of benzene at 26° C. is obtained by following the line ABCDE from the molecular weight (78.1) to the critical pressure (48.6 atmospheres), to the critical temperature (562 K.), to the vapor pressure at 26° C. (100 millimeters of mercury) and finally down to the estimated viscosity 0.56 centipoise. The observed value at this temperature is 0.59 centipoise.

(b) The second application is to predict the viscosity of a liquid at a different temperature based on one known value. Thus, suppose the viscosity of methyl acetate at its boiling point is required knowing that at 24° C. when the vapor pressure is 200 millimeters of mercury the viscosity is 0.37 centipoise.

The sequence of operation is shown by following the line FGHJ. The predicted boiling point viscosity is 0.26 centipoise. Extrapolation of available data on an Othmer viscosity plat yields a value of 0.27 centipoise.

e. Variation with Temperature: No simple relationship exists between liquid viscosity and temperature such as exists for gas viscosities (Section 2e.). Equation 16 can be used to relate the change in viscosity with temperature to the temperature coefficient of vapor pressure. Also, Thomas' Equation 13 relates the change of viscosity with the change in density and temperature.

For short temperature ranges the Andrade equation[2]

$$\mu = A\, e^{B/T} \qquad (17)$$

provides the simplest means of relating liquid viscosity to temperature.

Example 19. Figure 8 illustrates the method of plotting suggested by Equation 17. Viscosity is plotted against 1/T on semi-logarithmic paper. Straight lines are obtained over short temperature intervals. The equation for the line for acetic acid is obtained as follows:

Using the values for points *M* and *N*, the slope term

$$B = \frac{\log 1.30 - \log 0.43}{0.00344 - 0.00268} = \frac{0.480}{0.00076} = 632$$

From point *M*,

$$A = \frac{1.30}{e^{632/291}} = \frac{1.30}{8.60} = 0.151$$

The equation predicting viscosities of acetic acid from 18 C. to 100 C. is:

$$\mu = 0.151\, e^{632/T}$$

f. Other Equations for Liquid Viscosity: The literature contains many other equations which have been proposed for representing the viscosity of liquids over a range of temperature or for estimating a liquid viscosity at one temperature. Some of these are listed below.

Gutman and Simmons[19]: This equation is similar to the Antoine equation for vapor pressure.

$$\log \mu = A + \frac{B}{T + C} \qquad (18)$$

where *A*, *B*, and *C* are to be determined for each compound.

Douglas[16]: This equation predicts liquid viscosities well if all the constants α, β, γ, δ, for each compound are known. It is a modification of Andrade's equation.

$$\mu = (\alpha\, e^{\beta/T} + \gamma\, e^{\delta/T})T \qquad (19)$$

Lautie[25]:

$$\phi = \frac{(a + b\,T)^x}{c - b\,T} \qquad (20)$$

Lewis[26]: This correlates the viscosities of a homologous series.

$$\log \mu = \frac{A}{T} \log M + x \log [p] + \log y \qquad (21)$$

Another form[27] is

$$\log [p]^{\frac{2}{3}} \mu = (A \log M - B)\frac{1}{T} - C \qquad (22)$$

Albright and Lohrenz[1]: Based on Eyring's theory of absolute reaction rates, two equations were proposed to calculate the viscosity of saturated liquid. The equations can be used to extrapolate viscosity data over a large temperature range up to the critical temperature. But the use of the equations is rather restricted because they contain terms which are relatively difficult to obtain. The data of free energy of activation for flow, free volume and internal energy of vaporization are required.

They also presented an empirical relationship, viz., that the plot of viscosity of saturated liquid against the product of compressibility of the liquid and its critical compressibility on log-log coordinate is a straight line. For extrapolation or interpolation of liquid viscosity for different temperatures, it only requires a simpler plot of viscosity against the liquid compressibility on log-log scales.

Many other equations exist. Some of these, for example those proposed by Panchenkov, are too complicated for use in process design and are not included here.

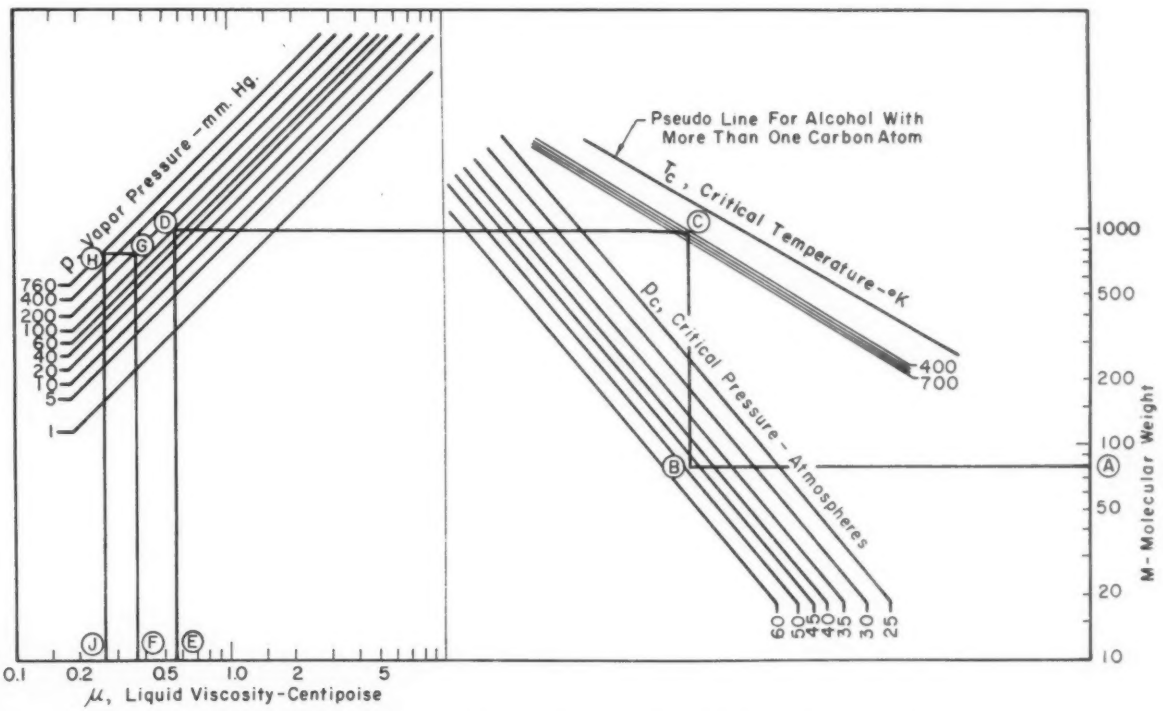

FIGURE 7—This plot will help you solve the semi-empirical equation for viscosity.

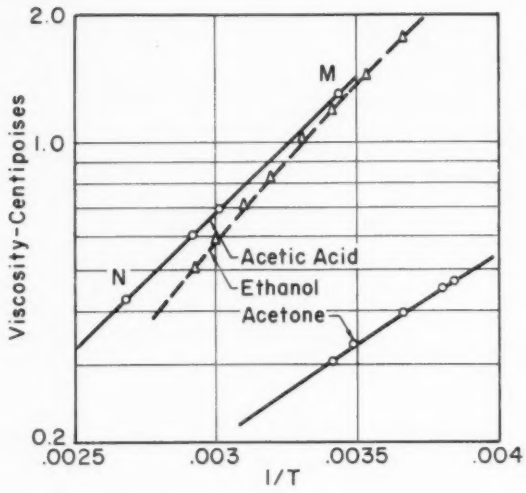

FIGURE 8—The Andrade equation provides a simple relation between liquid viscosity and temperature.

NOMENCLATURE

A	Characteristic constant in Equation 11
A	Empirical constant in Equations 17, 18 21, and 22
B	Characteristic constant in Equation 11
B	Empirical constant in Equations 17, 18, and 22
C	Constant in Equation 13, 0.0670 for non-associated liquids
C	Empirical constant in Equations 18 and 21
D	Liquid density, gm. per cubic centimeter
I	Souders' Viscosity constitution constant in Equation 3, determined by Table 2
K	Structural constant in Equation 13, determined by Table 3
M	Molecular weight
[P]	Parachor
[R]	Rheochor
$[R_D]$	Molar refraction corresponding to sodium D line
T	Temperature, °K
T_c	Critical temperature, °K
T_c'	Pseudo critical temperature, °K
T_r	Reduced temperature
T_r'	Pseudo reduced temperature
a	Constant in Equation 20
b	Constant in Equation 20
c	Constant in Equation 20
d	Constant in Equation 20
d	Vapor density, gm. per cu. cm.
p	Pressure, atm.
p'	Pressure, mm. Hg.
p_c	Critical pressure, atm.
p_c'	Pseudo critical pressure, atm.
p_r	Reduced pressure
p_r'	Pseudo reduced pressure
v	Specific volume, cu. cm. per gram
v	Velocity, cm. per second in Equation 1
x	Distance, cm. in Equation 1
x	Constant in Equations 20 and 21
y	Constant in Equation 21
α	Constant in Equation 19
β	Constant in Equation 19
γ	Constant in Equation 19
γ	Surface tension, dynes per cm.
δ	Constant in Equation 19
ϕ	Fluidity, rhes
Φ	Function defined by Equation 7
τ	Shearing force, dynes per cm.
μ	Viscosity, centipoise
$\bar{\mu}$	Viscosity, poise
μ'	Viscosity, micropoise
μ''	Viscosity, millipoise
μ_i'	Critical viscosity, micropoise
μ_m	Viscosity of mixture, micropoise
μ_r	Reduced viscosity
ν	Kinematic viscosity, stokes
η	Viscosity, lb/(hr.)(ft.).

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Find Heat Losses Graphically

A series of graphs and nomographs is presented which shortens heat loss and insulation calculations and gives excellent over-all accuracy

Charles R. Kise
Baldwin-Hill Company
Trenton, N. J.

THE CALCULATION of heat transmission through an insulating material is very simple when the temperature of both the hot and cold faces is known. In actual practice, however, the problem usually requires a designer to estimate the saving in heat that can be made by applying insulation to a hot object, and the temperature of the external surface is unknown. It is then necessary to assume temperature values for the external surface, calculate the heat transmission through the insulation, and balance this against the heat loss from the surface.

This procedure is not as simple as it sounds. It involves tedious cut-and-try calculations and the solution of complex formulas. Accurate solution is a very laborious process. As a result, designers often use generalized curves or inaccurate rules-of-thumb to avoid performing monotonous and complicated mathematics. A series of graphs and nomographs is presented which will permit the designer to perform heat loss and insulation calculations simply, with a minmum of time and effort and with excellent over-all accuracy.

HEAT LOSS FROM HOT SURFACES

The problem of determining heat transmission through insulation is inseparable from the calculation of heat loss from the external surface. Presented first will be graphical methods for determining surface heat losses from all types of regularly shaped surfaces.

Generalized curves showing surface heat loss are valuable for quick, rough approximations, but may be far from accurate when ambient conditions and surface emissivity are different from the values assumed to make the curves. There are also large variations with the type of surface (flat or cylindrical) and its orientation (horizontal or vertical). Specific calculations, however, are somewhat wearisome, involving absolute temperatures, fourth powers, and fractional powers. The engineer is therefore often apt to conclude that life is too short and to place his trust in an approximate curve.

The solution of such problems can be vastly simplified with the aid of nomographs or alignment charts and curves. Where surface temperature and ambient conditions are known, such devices make it possible to solve specifice problems with only the simplest of slide rule calculations and with a respectable degree of accuracy. The additional problem of determining the surface temperature when insulation is used will be dealt with later.

A hot surface transmits heat to the atmosphere by radiation and convection. Factors combining the two heat losses are so extremely limited in use that any pretense of accuracy requires that radiation and convection be treated separately.

Radiation. The commonly accepted formula for radiation loss is:

$$q_r = .172\, e \left[\left(\frac{T_s}{100} \right)^4 - \left(\frac{T_a}{100} \right)^4 \right] \qquad (1)$$

(See Nomenclature for definitions of terms.)

If this formula is divided by $(t_s - t_a)$ it will then be in a form suitable for use in constructing an alignment chart, giving an answer in terms of btu per hour per sq ft per degree of temperature difference between the surface and its surroundings.

Figure 1 is so constructed. To use it, simply connect the points for ambient temperature and surface temperature with a straight edge and read the coefficient of heat transfer (h_r). Surface radiation loss (q_r) then equals $h_r\ (t_s - t_a)$.

Figure 1 is based on a surface having $e = 0.90$, which is a satisfactory value for bare steel or dark colored paint on metal. For other emissivities, multiply by the ratio of

Find Heat Losses Graphically . . .

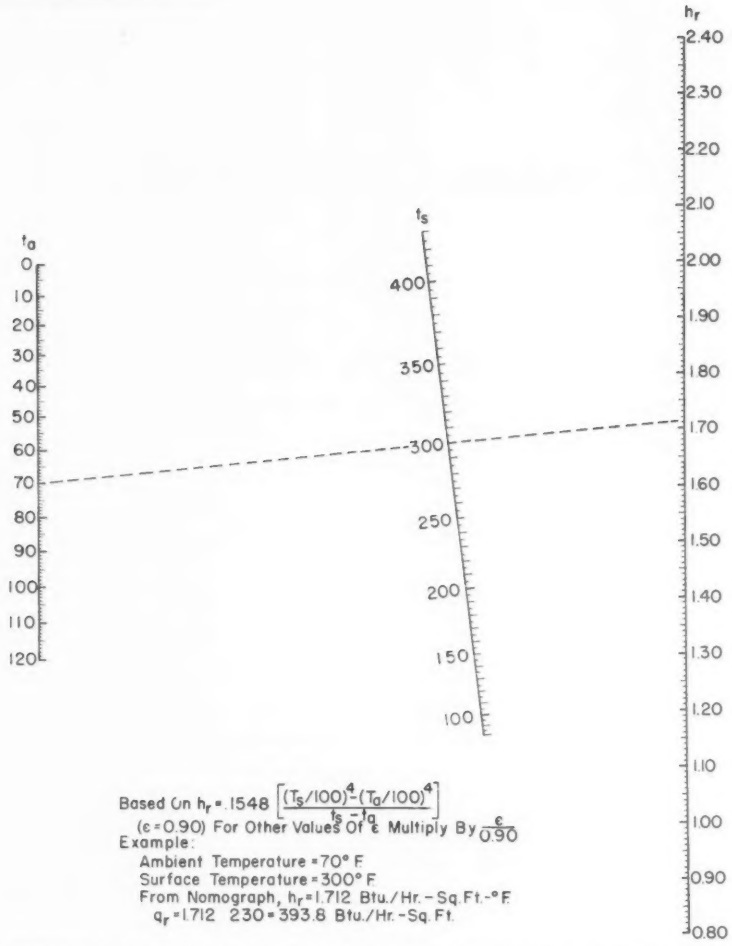

FIGURE 1—Radiation heat loss from hot surfaces is read directly from this chart.

the actual emissity to 0.90. That is $\left(h_r \cdot \frac{\epsilon}{0.90} \right)$. Table 1 lists emissivities for a few of the more common surfaces.

Natural Convection. For a hot surface **in still air,** the best available formula for convection heat loss appears to be:[3]

$$q_c = 0.7383 \left(\frac{1}{T_{avg}} \right)^{0.181} (t_s - t_a)^{1.266} \qquad (2)$$

The constant 0.7383 is used for a vertical flat surface at least two feet high. Other constants or correction factors are available for cylinders and for other surface orientations. Here again the formula can be divided by $(t_s - t_a)$ to provide figures suitable for constructing an alignment chart. Such a diagram is reproduced as Figure 2a in which the coefficient of heat transfer (h_c) is given directly for flat vertical surfaces at least two feet high. Correction factors are shown for horizontal surfaces facing up and down.

For pipes and other cylinders, Figure 2a should be used in conjunction with Figure 2b which gives correction factors corresponding to diameter and orientation.

TABLE 1—Surface Emissivities[1, 2]

Commonly used for bare steel, dull or dark paint, brick, or roofing	0.9
Aluminum	0.05—0.10
Steel, oxidized	0.27—0.69
Asbestos cloth or paper	0.90—0.94
Porcelain enamel, white	0.92
Wood	0.82—0.92
Paints	
Black, shiny	0.82—0.88
Black, flat	0.96—0.98
Oil paints, various colors	0.77—0.96
Aluminum	0.27—0.67
Bronze	0.51

Forced Convection. Installations exposed to the wind are subject to much higher heat losses. There are many variables encountered, experimentation is difficult, and there are no universally-accepted formulas.

For flat surfaces, the following formula has long been used, and is plotted as curve A in Figure 3:

$$h_c = 1 + 0.225v \qquad (3)$$

Research carried on by the A.S.H.V.E. indicates that lower values of h_c may be more accurate, particularly for

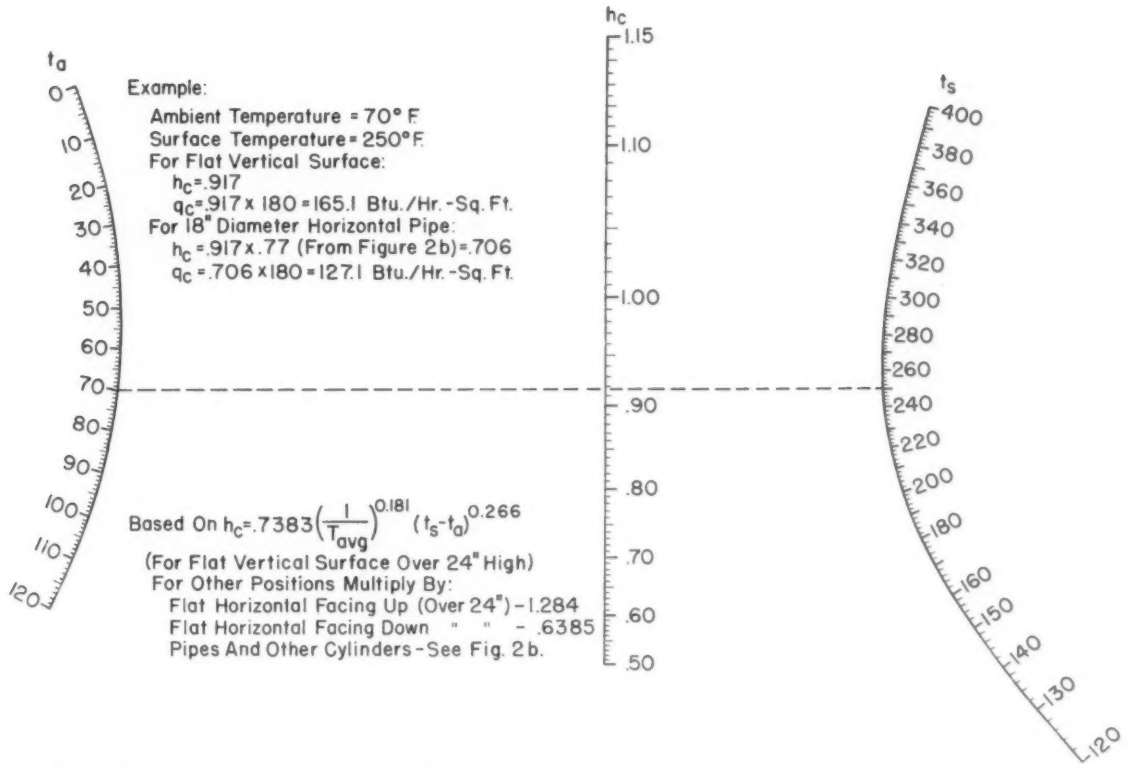

FIGURE 2a—Convection heat loss for flat surfaces is given directly from this chart. For pipes and other cylinders use in conjunction with Figure 2b.

surfaces of considerable length. Curves *B*, *C*, and *D* in Figure 3 represent suggested approximate values of h_c for air temperatures between 0 and 90 F, based on data from this research.[4]

Pipes and other cylindrical surfaces exposed to wind or air currents are a knottier problem. There is no one formula or simple relationship that can be used for a wide range of conditions. McAdams[4] has correlated data from many investigators covering heat loss for single cylinders with air flow at right angles. Figure 4 is based on this correlation (extrapolated for higher Reynolds' numbers) and will be found to simplify such estimates greatly.

Heat loss from any common type of surface of known temperature can now be found; using Figure 1 for radiation loss, and the appropriate selection from Figures 2 to 4 for convection loss.

Figure 5 is added for rapid approximation of the areas of pipes of various diameters.

The following examples may be useful in explaining the use of the diagrams.

Example 1—An indoor 8-inch pipe line (8⅝-inch OD) carries steam at 250 F. The line is mostly horizontal and ambient temperature averages 65 F. What would be the heat loss if the line were not insulated?

From Figure 1:	h_r =	1.49
From Figures 2a and 2b:	$h_c = .925 \cdot .89$	.82
	h =	2.31

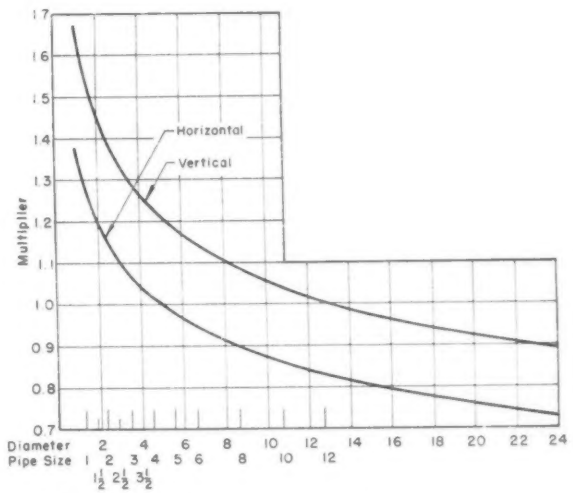

FIGURE 2b—Use these multipliers for natural convection loss from cylindrical surfaces in conjunction with Figure 2a.

$q = h\,(t_s - t_a = 2.31\,(250 - 65) =$
427 Btu/hr per sq ft

From Figure 5, $q' = 427 \cdot 2.26 =$
965 Btu/hr per foot of pipe.

If line is painted aluminum, h_r is reduced to $1.49 \cdot \frac{.50}{.90} = .83$ and q' = approx. 690 Btu/hr per foot of pipe.

Example 2—An outdoor test facility includes a 24-inch OD pipe, internally insulated, carrying air at 1,200 F. It is desired to limit

Find Heat Losses Graphically . . .

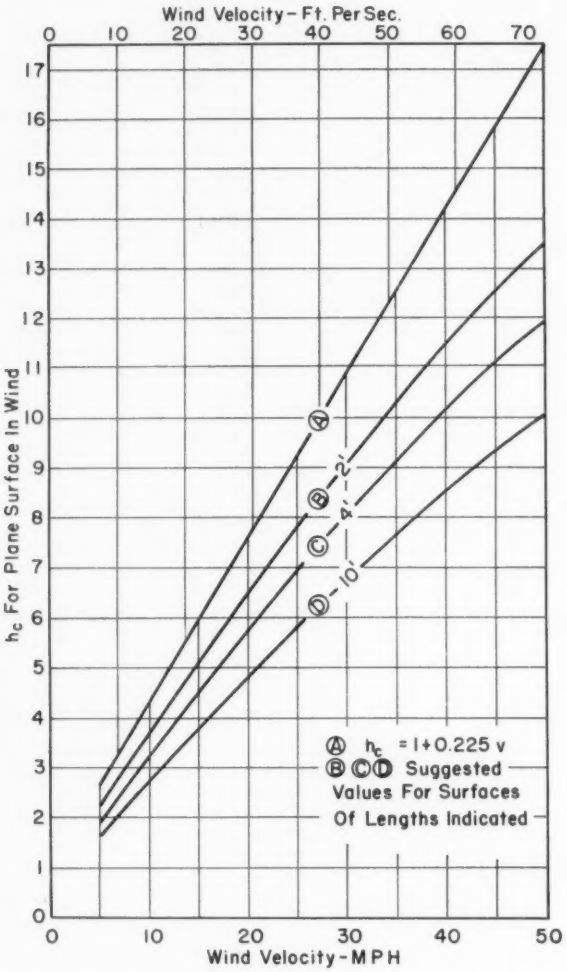
Wind Velocity - Ft. Per Sec.
0 10 20 30 40 50 60 70
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
h_c For Plane Surface In Wind
Ⓐ h_c = 1+0.225 v
ⒷⒸⒹ Suggested Values For Surfaces Of Lengths Indicated
Ⓐ
Ⓑ 2'
Ⓒ 4'
Ⓓ 10'
0 10 20 30 40 50
Wind Velocity - MPH

FIGURE 3—Forced convection heat losses for flat surfaces exposed to wind are picked directly from this chart.

heat loss to 4,000 Btu per hour per foot of pipe under average ambient conditions of 50 F. with 20 mph wind. What will the pipe temperature be under those conditions?

From Figure 5: pipe area = approx. 6.3 sq ft per foot.

$q = 4{,}000 \div 6.3 = 635$ Btu per hr per sq ft.

Since trial and error is involved, try two points, $t_s = 150$ and 200 F.

		$t_s = 150$	$t_s = 200$
From Figure 1:	$h_r =$	1.10	1.26
From Figure 4:	$h_c =$	5.10	5.10
	$h =$	6.20	6.36
	$t_s - t_a =$	100	150
	$q = h\,(t_s - t_a) =$	620	955

This indicates that the surface temperature will have to be limited to approximately 150 F. to keep the heat loss within the desired limits.

It should be noted that Figure 4 is based on a film temperature, or average of surface and air temperatures, of 140F, and includes a correction curve for lower or higher film temperatures. The correction is small, however, and in view of the limits of accuracy of known data and of the alignment chart it is recommended that this factor be ignored unless it is at least 2 percent.

HEAT LOSS THROUGH INSULATION (PLANE SURFACES)

In problems of heat loss and heat transmission the flow is generally expressed in Btu per hour per sq ft (q), and the potential is the difference in temperature ($t_1 - t_2$ or Δt). The rate of steady-state heat flow between two areas at different temperatures is expressed:

$$q = \frac{\Delta t}{R} \qquad (4)$$

With heat losses from surfaces in the air Δt equals $t_s - t_a$ and the resistance (R) is the reciprocal of the over-all heat transfer coefficient h, so that:

$$q = \frac{\Delta t}{R} = \frac{t_s - t_a}{1/h} = h\,(t_s - t_a) \qquad (4,1)$$

Figure 6 illustrates a common situation in which insulation of a certain thickness (x) has been applied to the outside of a flat-sided vessel. The temperature on the inside, on the surface, and the ambient temperature are represented as t_i, t_s and t_a respectively. There are three potentials or differential temperatures to be considered: $t_i - t_s$; $t_s - t_a$; and $t_i - t_a$. If the resistance of the insulation is called R_i, the equation for heat flow can be written three ways:

$$q = \frac{t_i - t_s}{R_i} = \frac{t_s - t_a}{1/h} = \frac{t_i - t_a}{R_i + 1/h} \qquad (4,2)$$

This states, among other things, the obvious fact that for a given area the rate of heat transfer through the insulation is the same as the heat loss from the surface to the atmosphere.

The resistance (R_i) of the insulation depends upon its thickness (x) and upon its thermal conductivity. The latter is expressed as the familiar coefficient k, whose units are btu per hr per sq ft per deg F for a thickness of one inch. The resistance of the insulation can be expressed:

$$R_i = x/k \qquad (5)$$

The coefficient (k) varies, not only with the nature of the material, but also with its temperature. Thermal conductivity (k factor) data therefore are usually given in curve form or at enough points so that a curve can be drawn which will permit selection of the proper value corresponding to the mean temperature through the insulation. The mean temperature is the average of the inside and surface temperatures:

$$t_m = (t_i + t_s)/2.$$

Figure 7 shows k factors for many of the more common industrial insulations. The values shown will usually be safe for conservative estimating purposes, but more accurate results can be obtained with manufacturers' data for the specific products under consideration. The temperature limits listed in Figure 7 are commonly used as

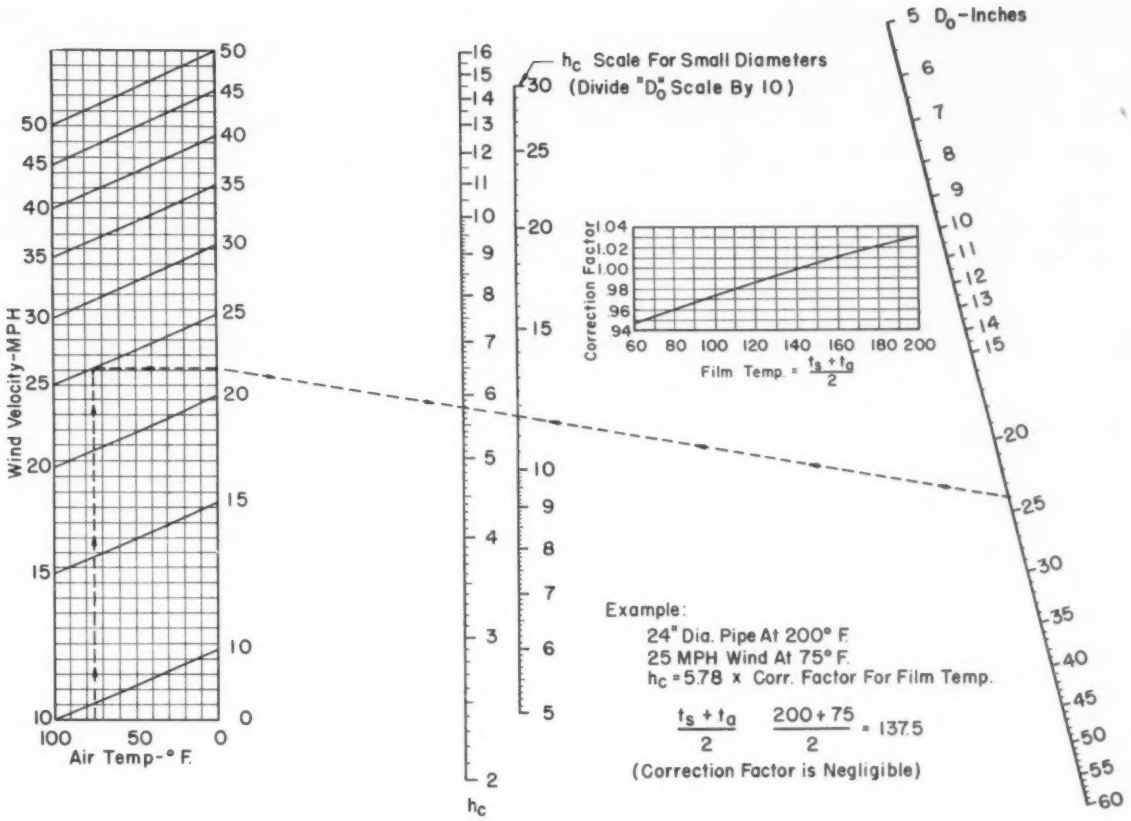
Wind Velocity-MPH
Air Temp-° F.
h_c Scale For Small Diameters
(Divide "D_o" Scale By 10)
h_c
5 D_o-Inches
Correction Factor
Film Temp. = $\frac{t_s + t_a}{2}$
Example:
24" Dia. Pipe At 200° F.
25 MPH Wind At 75° F.
h_c = 5.78 x Corr. Factor For Film Temp.
$\frac{t_s + t_a}{2}$ $\frac{200+75}{2}$ = 137.5
(Correction Factor is Negligible)

FIGURE 4—Convection heat losses for pipe in wind are given directly from this chart.

maximum allowable hot face temperatures, but are not necessarily correct for specific products.

We previously dealt with the heat loss from a surface of known temperature. As previously pointed out, however, when insulation is applied the exterior of the insulation becomes the surface exposed to the air, and the temperature of this surface is unknown. The unknown temperature and the heat flow can both be found, however, by making use of the fact that the heat transmitted through the insulation is equal to that lost from the surface:

$$q = \frac{t_i - t_s}{R_i} = h\,(t_s - t_a)$$

By trial and error we can find a surface temperature at which the two sides of the equation will balance. Still better, we can plot t_s vs. q for both sides of the equation on the same graph and find the point of intersection. The recommended procedure, illustrated in Figure 8, is as follows:

a. Make a rough guess at the surface temperature, and select two other points say 25 to 50 degrees above and below this value. For each of the three points find; h (equals $h_r + h_c$) from Figures 1-5, and $q = h\,(t_s - t_a)$.

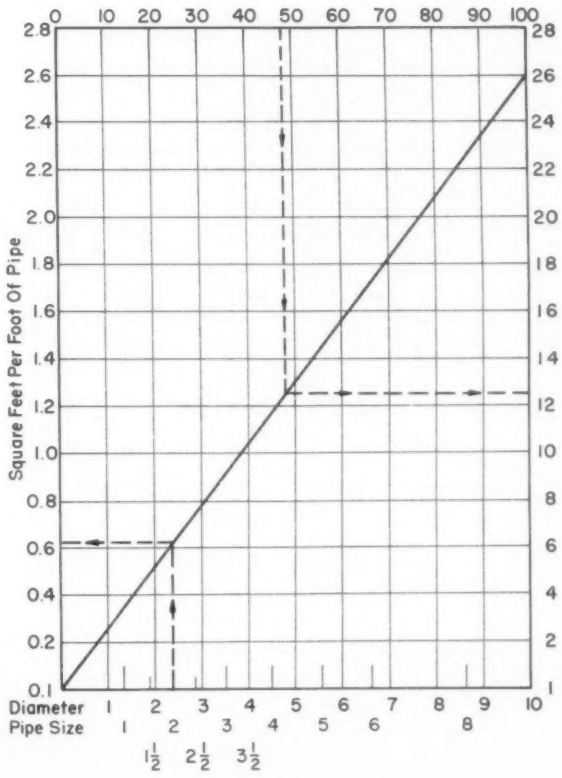

FIGURE 5 (right)—Use this chart for quickly determining the surface area of pipe and small cylinders.

Find Heat Losses Graphically . . .

b. Plot these points with t_s for the "x" axis and q for the "y" axis, and connect them with a smooth curve.
c. For the middle value of t_s, find the mean temperature through the insulation and the corresponding k factor. Then $R_1 = x/k$ and $q = (t_i - t_s)/R_1$. Plot this point on the graph.
d. If this point falls to the left of the surface loss curve, try another point at a higher surface temperature. If it is to the right of the curve try a lower temperature. Repeat the procedure as in Step c, and plot the point on the graph.
e. Connect the two points from Steps c and d with a straight line. The intersection of this line with the surface loss curve indicates the correct surface temperature and the corresponding heat loss per square foot.

In the following example, the steps are numbered as above.

Example 3—A furnace is to operate at 1,200 F., and is to be in an indoor location with an average ambient temperature of 80 F. Find the surface temperature and heat loss for the vertical furnace walls if insulated with 2 inches of material having a k factor of .40 at 300 F.; .52 at 600 F.; and .70 at 900 F.

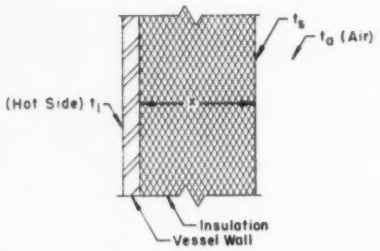

FIGURE 6—Temperature points for section through insulated surfaces.

Thermal Conductivity of Industrial Insulations

FORM	MATERIAL	Temp. Limit	Curve Figure 7
Blankets	Mineral Wool		
	Metal Reinforced	1200	A
	Felt Type	450	B
Pipe Insulation, Blocks & Boards	Asbestos		
	Molded Amosite & Binder	1200	C
	Corrugated Laminated Paper—4 Ply	300	D
	Corrugated Laminated Paper—6 Ply	300	E
	Corrugated Laminated Paper—8 Ply	300	F
	Calcium Silicate & Asbestos	1200	K
	Cellular Glass	800	L
	Diatomaceous Silica	1500	G
	Diatomaceous Silica	1900	H
	85% Magnesia with Asbestos	600	J
Blocks & Boards	Mineral Wool—High Temp. (Resin Bonded)	600	A
	Mineral Wool—High Temp. (Inorganic Binder)	1600	K
Cements	85% Magnesia with Asbestos	600	M
	Mineral Wool with Colloidal Clay Binder	1800	N

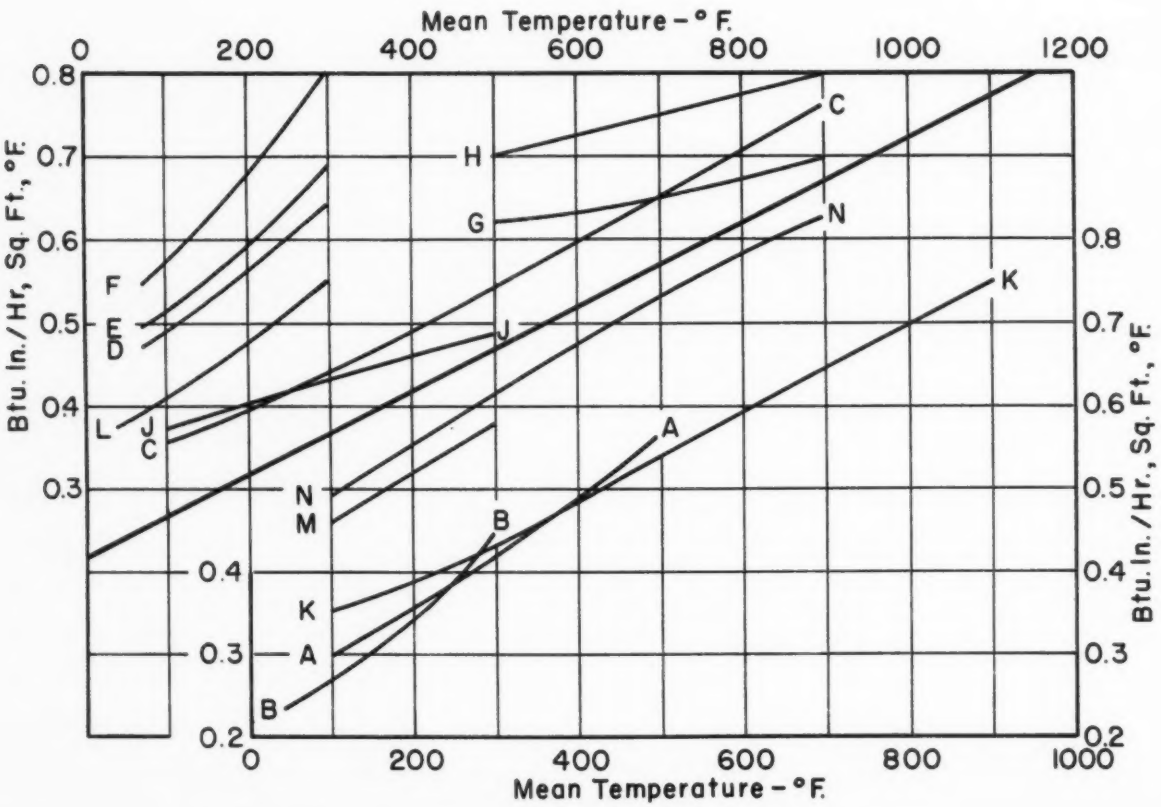

FIGURE 7—Thermal conductivity (k factors) for common industrial insulation materials.

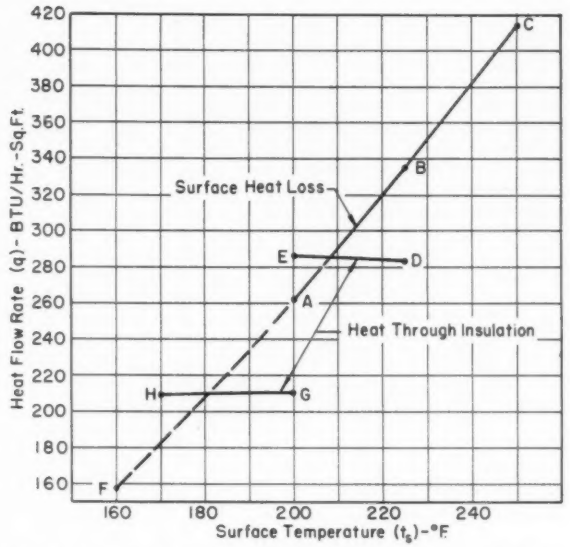

FIGURE 8—This graphical solution for Examples 3 and 4 gives the surface temperature of insulation with a minimum of trial and error.

a. Surface heat loss:

	A	B	C
Assume: t_s	200	225	250
t_a	80	80	80
$t_s - t_a$	120	145	170
h_r (from Figure 1)	1.35	1.44	1.54
h_c (from Figure 2a)	0.83	0.87	0.90
h	2.18	2.31	2.44
$q = h\,(t_s - t_a)$	262	335	415

b. Plot t_s vs. q (Figure 8, points *A*, *B*, and *C*)

c. Heat through insulation, middle point:

t_i 1200 — $t_i + t_s$ 1200
t_s 225 — 225
$t_i - t_s$ 975 — 1425

$t_m = 1425 \div 2 = 713$

k factor (from a curve of the known points) = 0.581 at 713°

$$R_1 = \frac{x}{k} = \frac{2}{0.581} = 3.44$$

$$q = \frac{t_i - t_s}{R} = \frac{975}{3.44} = 283 \text{ Btu per square foot}$$

Plot this point on the graph (Figure 8, point *D*)

d. This point falls to the right of the surface loss curve, so try $t_s = 200$. This gives $k = 0.572$; $R_i = 3.49$; and $q = 286$. Plot 286 Btu per square foot at 200° (Figure 8, point *E*).

e. Connect the last two points and note that the line (*DE*) intersects the first curve at 208 to 209 F. and 285 Btu per square foot. This is the answer sought.

Compound Insulation—In some cases it may be desirable to use two or more layers of insulation of different types, as in Figure 9.

The left side of our heat balance equation now becomes:

$$\frac{t_i - t_s}{R_1 + R_2} \text{ or } \frac{t_i - t_s}{\frac{x_1}{k_1} + \frac{x_2}{k_2}}$$

The solution of a practical problem of this type involves more factors than the case of simple insulation, but the fundamental basis is the same. The following example will show how to modify the procedure.

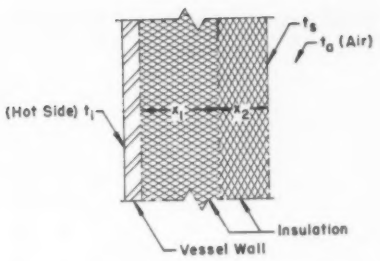

FIGURE 9—Temperature points for section through compound insulated surfaces.

Example 4—On the furnace described in Example 3, the heat loss is to be further reduced by adding a layer of low temperature insulation on top of the 2-inch thick material. The outer insulation is to be 1-inch thick, with a k factor of 0.34 at 200 F., 0.42 at 300 F., and 0.50 at 400 F.

The curve for surface heat loss has already been established, but obviously will have to be extended downward. From Figures 1 and 2a at $t_s = 160°$: $h_r = 1.21$; $h_c = .75$; $h = 1.96$; and $q = 157$. Plot this point, (Figure 8, point *F*) and draw the lower portion of the curve.

The temperature drop through each material is proportional to the resistance of that material. With this in mind, proceed as follows:

a. Make a rough estimate of the individual and total resistances in order to approximate the temperature drop through each material. The given data indicates that the split will be something like this:

	Thickness "x"	k Factor	Resistance $R = x/k$
Inner material	2"	0.6	$3.33 = R_1$
Outer material	1"	0.4	$2.50 = R_2$
			$5.83 = R$

The ratio of the temperature drop through the first material to the total temperature drop will be the same as the ratio of its resistance to the total resistance.

$$\frac{\Delta t_1}{\Delta t} = \frac{R_1}{R} = \frac{3.33}{5.83}$$

b. Now let us assume a surface temperature of 200 F. Then:

$$\Delta t = t_i - t_s = 1{,}000$$

$$\Delta t_1 = \Delta t \frac{R_1}{R} = 1{,}000 \cdot \frac{3.33}{5.83} = 571$$

Interface temperature = 1,200 — 571 = 629
Mean insulation temperatures:

$$\text{Inner material } \frac{1{,}200 + 629}{2} = 915$$

$$\text{Outer material } \frac{629 + 200}{2} = 415$$

c. With this information, we can refer to the k factor curves for conductivity data and make a more educated guess as to the resistance and temperature drops.

	Mean Temp.	k Factor	x	$R = \frac{x}{k}$
Inner material	915	0.712	2	2.81
Outer material	415	0.512	1	1.95
				4.76

$$q = \frac{t_i - t_s}{R} = \frac{1{,}000}{4.76} = 210$$

Plot this point on the graph (Figure 8, point *G*) 210 Btu at 200 F.

d. Since this point falls to the right of the curve, our next point should be at a lower assumed value of t_s. Let's assume $t_s = 170$, and use the resistance values from Step c to find closer values for the mean insulation temperature.

$$\Delta t = 1{,}200 - 170 = 1{,}030$$

$$\Delta t_1 = 1{,}030 \cdot \frac{2.81}{4.76} = 608$$

Find Heat Losses Graphically . . .

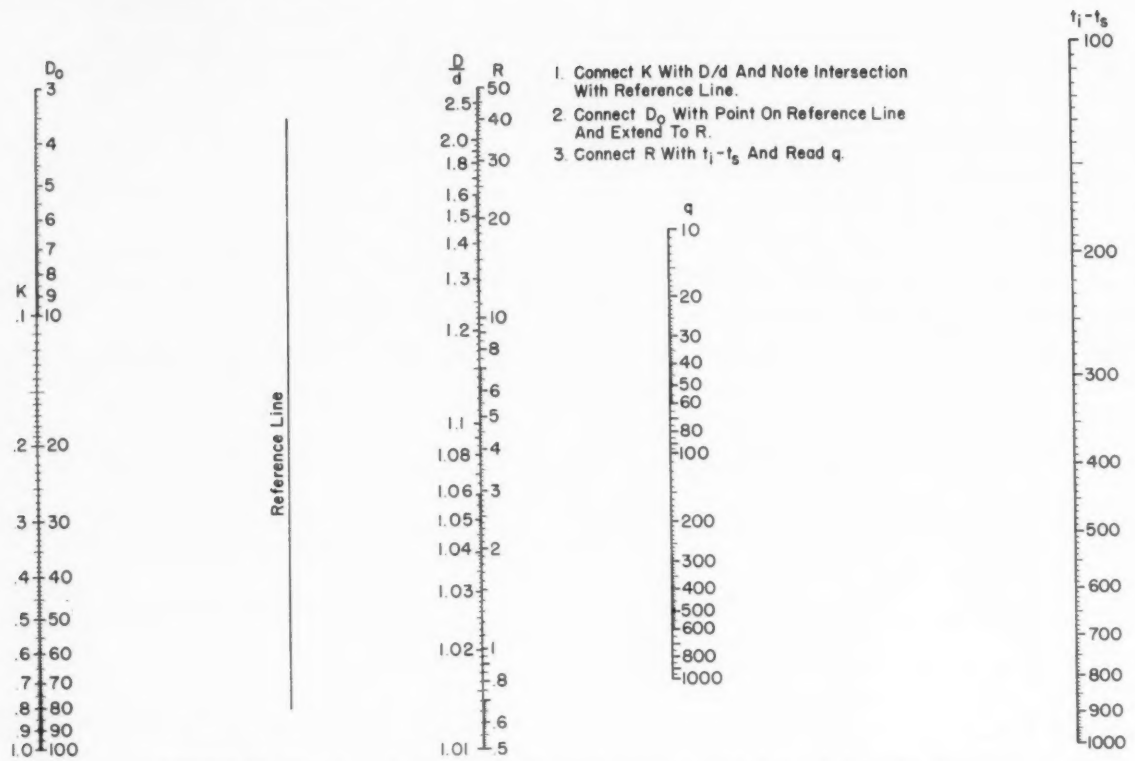
D_o
K
Reference Line
$\frac{D}{d}$
R
1. Connect K With D/d And Note Intersection With Reference Line.
2. Connect D_o With Point On Reference Line And Extend To R.
3. Connect R With $t_i - t_s$ And Read q.
q
$t_i - t_s$

FIGURE 10—Heat losses from pipe insulation surfaces can be picked directly from this chart.

Interface temperature = 1,200 — 608 = 592
Mean insulation temperatures:

$$\text{Inner material} \quad \frac{1,200 + 592}{2} = 896$$

$$\text{Outer material} \quad \frac{592 + 170}{2} = 381$$

c. Again refer to the k factor curves, and tabulate:

	Mean Temp.	k Factor	x	$R = \frac{x}{k}$
Inner material	896	0.696	2	2.88
Outer material	381	0.486	1	2.06
				4.94

$$q = \frac{t_i - t_s}{R} = \frac{1,030}{4.94} = 209$$

Plot 209 Btu at 170 F. on the graph (Figure 8, point *H*) and connect this point with point *G*. The line (*GH*) intersects the surface heat loss curve at $t_s = 181$ F. and $q = 209$ Btu. A final check can be made at this point if desired.

Some problems involve three or more thicknesses of different materials. In such cases:

$$q = \frac{t_i - t_s}{R_1 + R_2 + R_3 \ldots} = \frac{t_i - t_s}{\frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} \ldots} \qquad (6)$$

Problems of this type are solved in the same way as Example 4. Just remember that the temperature drop through each material is equal to the total temperature drop times the ratio of the resistance of that material to the total resistance.

HEAT LOSS THROUGH INSULATION (CYLINDRICAL SURFACES)

The cylindrical arrangement offers a diverging path for the flow of heat. Formulas become more complicated than for plane surfaces, and may be expressed in terms of either Btu per foot of pipe or Btu per square foot. The heat flow through the insulation, however, must be balanced against the combined radiation and convection loss from the surface to the atmosphere. Since our previous data and alignment diagrams for surface heat loss are on a square foot basis, it is preferable to keep the calculation for pipe insulation on the same basis so that direct comparisions can be made.

This means that we will still be working with the same fundamental formula in which the heat flow per square foot of external surface is expressed as:

$$q = \frac{\Delta t}{R} = \frac{\Delta t}{\left(\frac{x}{k}\right)} \qquad (4)$$

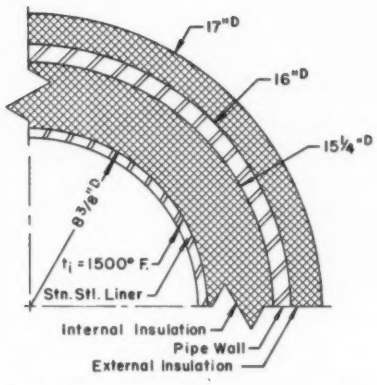

FIGURE 11—Temperature points for an internally insulated pipe with some external insulation.

Because of the divergent heat path, however, we can no longer use the actual thickness (x) of the insulation, but must substitute an expression for equivalent thickness (x_e) which takes into account the external diameter D_o and the ratio D/d of outer and inner diameters of the insulation.

$$x_e = 1.1513\, D_o \log \frac{D}{d}$$

Therefore:

$$q = \frac{\Delta t}{\left(\frac{1.1513\, D_o \log \frac{D}{d}}{k}\right)} \qquad (7)$$

The alignment diagram, Figure 10, is based on this formula. It not only minimizes calculations but also eliminates the need to work with logarithms. To use the nomograph, first calculate by slide rule the ratio D/d (outer diameter of insulation divided by inner diameter of insulation.) Then list the basic data and proceed as follows.

a. Connect k factor with D/d, and note point of intersection with reference line.
b. Connect this point with D_o (outside diameter) and extend to R.
c. Connect R with $t_i - t_s$ and read q in Btu per square foot of external surface. (Or, if desired, use slide rule to find $q = (t_i - t_s)/R$.)

Example 5—A 6-inch pipe carrying steam at 250 F. is to be covered with 1 inch of pipe insulation of conductivity as shown by curve "J" in Figure 7. Find the surface temperature and heat loss for a horizontal run operating indoors with 80 F. ambient still air.

a. Establish a curve for surface heat loss.

Assume: t_s	120	140	160
t_a	80	80	80
$t_s - t_a$	40	60	80
h_r (from Figure 1)	1.09	1.15	1.21
h_c (from Figures 2a and 2b)	.60	.66	.71
h	1.69	1.81	1.92
$q = h\,(t_s - t_a)$	68	109	153

b. Plot these points on a graph similar to Figure 8 and draw a smooth curve through them as in previous examples.
c. Find heat transmitted through insulation for $t_s = 140$.

$t_i = 250$, $t_s = 140$, $t_i - t_s = 110$; $t_i = 250$, $t_s = 140$, $t_i + t_s = 390$

$t_m = 390 \div 2 = 195$
k (from Figure 7) = .40
d = 6.625
D = 8.625
D/d = 1.3
R = 2.8, q = 39 } from Figure 10

Plot this point on the graph.
d. This point falls to the right of the surface loss curve, so try $t_s = 100$.

$t_i - t_s = 150$
$t_i + t_s = 350$
$t_m = 175$
k = .395
q = 52 (from Figure 10)

Plot 52 Btu at 100 F.
e. Connect the last two points with a straight line. Our curve for surface heat loss is too high, but can be extended to find the answer at approximately 110 F. and 49 Btu per square foot.
f. This can be converted to Btu per foot of pipe on the basis of 8.625-inch diameter. From Figure 5 it can be found that the area is approximately 2.25 square feet per foot of pipe.

Compound Insulation. Figure 10 can also be used for compound pipe insulation; that is, for two or more layers of insulation having different conductivities. In such cases, the ratio D/d and the resistance are calculated separately for each layer. D_o, however, is always the diameter of the external surface. An example will help to clarify the procedure.

Example 6—A line to carry superheated steam at 1,500 F. is to be internally insulated so that ordinary carbon steel can be used for the piping. A thin external insulation will also be applied in order to further reduce the heat loss and to maintain the pipe wall temperature well above the condensation point. This construction is illustrated in Figure 11.

The insulating materials have conductivities as listed:

	Internal Insulation			External Insulation		
t_m	800	950	1,050	300	400	500
k factor	0.74	0.87	0.96	0.38	0.42	0.46

Find the surface temperature and heat loss based on average ambient conditions of 60 F. and 10 mph wind.

a. Start as usual by establishing the curve (as in Figure 8) for surface heat loss vs. surface temperature.

Assume: t_s	100	120	140
t_a	60	60	60
$t_s - t_a$	40	60	80
h_r (from Figure 1)	0.972	1.031	1.093
h_c (from Figure 4)	3.4	3.42	3.46
h =	4.372	4.451	4.553
$q = h\,(t_s - t_a)$ =	175	267	364

b. Line up data for calculation of heat transmission through the insulation:
(1) Draw k factor curves for internal and external insulations (k_1 and k_2).
(2) Note diameters and ratios:

$D_o = 17$

$$\frac{D}{d}\text{ (internal)} = \frac{15.25}{8.375} = 1.82$$

$$\frac{D}{d}\text{ (external)} = \frac{17}{16} = 1.062$$

c. As in Example 4 make use of the fact that the temperature drop through each material is proportional to the resistance of that material. Refer to the k factor curves for a first approximation of the conductivities. Then use Figure 10 to find the resistances:

Internal

For k = 0.9 $R_1 = 5.6$

External

For k = 0.4 $R_2 = 1.27$

Total $R = 6.87$

Then: $\frac{\Delta t_1}{\Delta t} = \frac{R_1}{R} = \frac{5.6}{6.87} = 0.815$

d. Assume a surface temperature of 120 F. Then:

$\Delta t = t_i - t_s = 1500 - 120 = 1380$, and

$\Delta t_1 = \Delta t \cdot \frac{R_1}{R} = 1380 \cdot .815 = 1125$

Pipe temperature = 1500 — 1125 = 375
Mean insulation temperatures and k factors:

Inner material $\frac{1500 + 375}{2} = 938$ ($k_1 = 0.86$)

Outer material $\frac{375 + 120}{2} = 248$ ($k_2 = 0.36$)

e. Use Figure 10 again with these new k factors to get:

$R_1 = 5.9$
$R_2 = 1.42$
$R = 7.32$

Then $q = \frac{t_i - t_s}{R} = \frac{1380}{7.32} = 189$

Plot this point on the graph. (Note: the "$t_i - t_s$" scale of Figure 10 goes to a maximum of only 1000. The chart can be used for higher values, however, by simply multiplying both the "$t_i - t_s$" and "q" scales by 10.)

f. The point just plotted on the graph falls to the right of the surface loss curve, so take the second trial at $t_s = 100$ and $t_i - t_s = 1400$

$\Delta t_1 = 1400 \cdot \frac{R_1}{R} = 1400 \cdot \frac{5.9}{7.32} = 1130$

Pipe temperature = 1500 — 1130 = 370
Mean temperatures and k factors:

Inner material $\frac{1500 + 370}{2} = 935$ ($k_1 = 0.86$)

Outer material $\frac{370 + 100}{2} = 235$ ($k_2 = 0.355$)

From Fig. 10:

$R_1 = 5.9$
$R_2 = 1.43$
$R = 7.33$
$q = \frac{1400}{7.33} = 191$

Plot 191 Btu at $t_s = 100$.

g. Connect the last two points plotted, and find the intersection with the surface loss curve at approximately 103 F. surface temperature and 190 Btu per square foot.

Pipe Wall Temperatures. In these examples it has been assumed that the temperature of the pipe or vessel wall is uniform through its thickness. Actually, there is a slight drop through the wall, but the amount is negligible in ordinary problems involving insulation. Where the pipe wall is very thick it may be desirable to check this point, particularly if the heat transfer rate is high.

Figure 10 can be used to determine Δt through the pipe wall in exactly the same way as finding Δt through insulation. Metal conductivities are very high, far beyond the range of the "k" scale. The latter scale, however, can be multiplied by 10, 100, or 1,000 providing the "R" scale is **divided** by the same amount. Be sure to use conductivities for a thickness of one inch. If the published data happens to give k for a length (thickness) of one foot, the given figure should be multiplied by 12 to get k for a one-inch thickness.

NOMENCLATURE

Symbols

h = Coefficient of heat transfer, Btu per hr per sq ft per deg F.
t = Temperature, deg F.
T = Absolute temp., deg R or deg F + 459.
$T_{avg} = \frac{T_s + T_a}{2}$
Δt = Temperature difference, deg F or deg R.
q = Rate of heat transfer, Btu per hr per sq ft of surface.
q' = Rate of heat transfer for pipe, Btu per hr per linear ft of pipe.
e = Emissivity
v = Air velocity, ft per sec.
D, d = Diameter, in. (when both are used, D is the larger and d the smaller of two diameters).
D_o = Outside diameter, in.
k = Coefficient of thermal conductivity, Btu per hr per sq ft per deg F. for a thickness of one inch.
x = Insulation thickness, in.

Subscripts

i = Inside
a = Ambient
s = Surface
m = Mean
r = Radiation
c = Convection

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About the Author

Charles R. Kise is chief engineer in the Insidline department, Baldwin-Hill Co., Trenton, N. J., where he handles the design of internal insulation installations for high temperature pipes and vessels, stress analysis, and heat loss calculations. He received a B.S. degree from Antioch College in 1931, and since then has gained experience in machine design, plant engineering, sales engineering, and part-time teaching during the engineering war training program. Kise is a professional engineer in New Jersey and Pennsylvania.

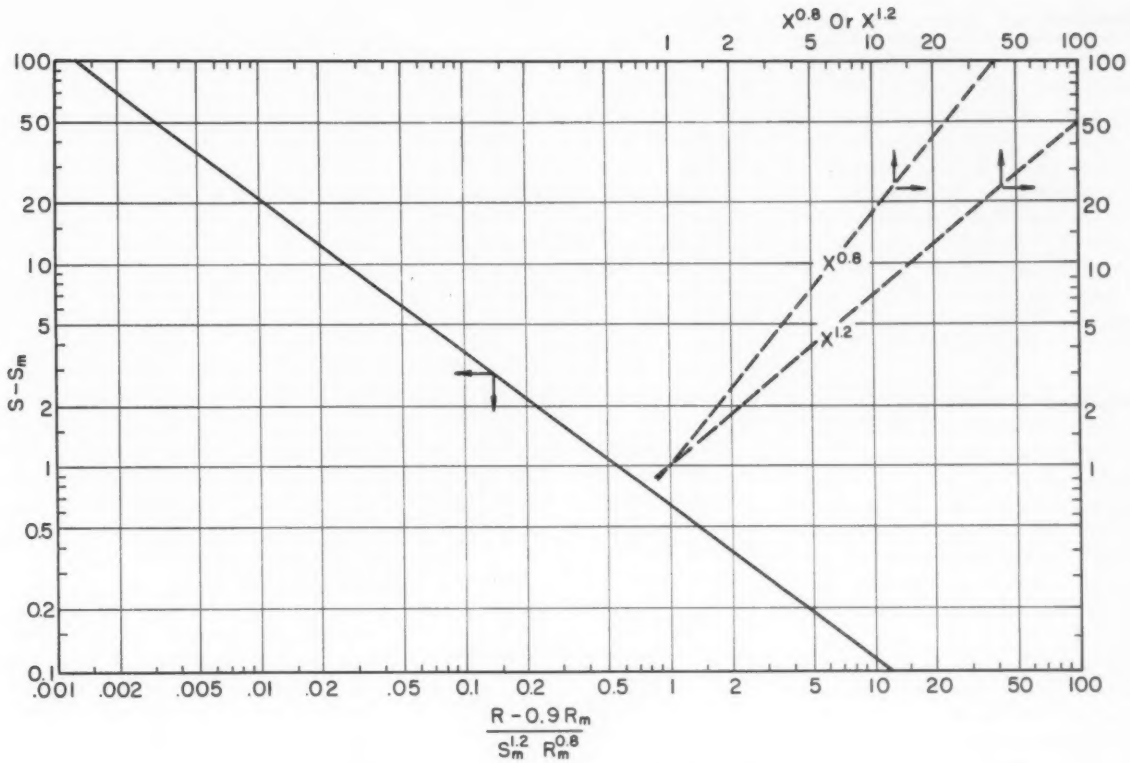

FIGURE 1—Number of Steps vs Reflux Ratio.

Straight line correlation . . .

Number of Trays vs. Reflux Ratio

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A STRAIGHT LINE correlation is given here for the rapid determination of the number of theoretical trays in a distillation column for finite reflux ratios. This correlation will give results which compare within 15 percent of the true value of the number of theoretical trays.

The minimum number of steps can be calculated easily by the familiar Fenske relationship,[1] and the value of the minimum reflux can be determined quite readily to a fair degree of accuracy, even for multicomponent separations, by one of the many short-cut methods, such as have been developed by Gilliland,[2] Colburn,[3] Schiebel & Montross[4] and Underwood.[5] Considerable computation is entailed, however, to obtain rigorously the number of steps corresponding to a given reflux ratio, except for the most simple type of fractionation. Because of this, a number of empirical correlations relating actual and minimum conditions have been developed: for example, those of Brown and Martin,[6] Gilliland,[7] and Donnell and Cooper.[8] Various degrees of accuracy are claimed for these correlations, but trials with the results of some low temperature fractionations of light hydrocarbons reveal appreciable error in some cases. Donnell and Cooper point out that accuracy is improved if a single check point of the correlation is available, i.e. if a value of S corresponding to a value of R is known in addition to S_m and R_m. A correlation line may then be drawn through this point following the same trend as the recommended line. This should be possibly the best way of using these correlations. Unfortunately, all are drawn as curves, so that this introduction of lines through check points is liable to error.

There seems to be a need, therefore, for a straight line correlation; any possible loss in accuracy by insistence on the straight line relation could be more than compensated for by greater reliability in drawing in lines through check points. An attempt at such a correlation has

been made here. That presented in this note is the final one of the many, which were tried and rejected on one ground or another, but nevertheless it is not suggested that it is the best that could be derived. Rather it is hoped that this correlation will stimulate the development of better straight line relations, based on rather more general data than were used for this one.

Proposed Correlation. The proposed correlation is shown in Figure 1. This is a log-log plot of $(S - S_m)$ against $(R - 0.9\,R_m)\,/S_m^{1.2}\,R_m^{0.8}$ and is a straight line joining points (.0012, 100) and (12, 0.1). (To assist in calculating abscissa values, plots of $S_m^{1.2}$ against S_m and of $R_m^{0.8}$ against R_m are also included in the figure).

If a check point, as suggested by Donnell and Cooper is available, then the correlating line should be drawn through this point, *parallel to the given correlation line.*

This type of correlation has the additional advantage that it can be readily expressed as an algebraic equation. The equation of the line in Figure 1 is:

$$\left(\frac{R - 0.9\,R_m}{R_m^{0.8}}\right)^{0.75}\left(\frac{S - S_m}{S_m^{0.9}}\right) = 0.66 \qquad (1)$$

Derivation of Correlation. The correlation is based mainly on the results of fractionation of multicomponent, non-ideal systems of light hydrocarbons at low temperatures. The number of trays required at actual reflux ratios was determined by tray-to-tray calculation.

As a start in the development of the correlation, it is assumed that an S vs R plot represents a simple hyperbolic curve to which S_m and R_m are asymptotes i.e.

$$(S - S_m)\,(R - R_m)^n = C. \qquad (2a)$$

where C is a constant for that curve.

Taking logarithms,

$$\log (S - S_m) = \log C - n.\log (R - R_m) \qquad (2b)$$

Trials show that, for a given separation, a plot of log $(S - S_m)$ against log $(R - R_m)$ does indeed give a straight line, except for low values of $R - R_m$ (R less than about 120% of R_m), when the actual values of S are lower than those indicated by the straight line relation.

This suggests that the approach of the curve to the S_m asymptote, in a plot of *S* vs *R*, is different from its approach to the R_m asymptote. Consideration of the pivoting of the fractionating operating line from minimum to total reflux value in the McCabe-Thiele diagram for a binary separation would confirm that this is so.

A reasonable approximation to symmetry is attained simply, however, by setting 0.9 R_m as a pseudo asymptote. That is, R_m in equations 2a and 2b is replaced by 0.9 R_m. Plots of log $(S - S_m)$ against log $(R - 0.9\,R_m)$ approximate closely to *straight lines.* It also turns out that the lines for different fractionations have very nearly *the same slope;* n in equations 2a and 2b approximates to a constant value of 0.75.

When log $(S - S_m)$ is unity, log C equals n. log $(R - 0.9\,R_m)$. The separation of the lines therefore depends on the value of C. Referring again to equation 2a, C is seen to determine the shape of the curve and might be said to reflect the "degree of difficulty" of the fractionation. It seems plausible to relate this "degree" to (a) the relative volatility of the key components involved, (b) the purity of the distillate, (c) the purity of the bottoms product and (d) the composition and condition of the feed to the fractionator. But (a), (b) and (c) are involved in setting the value of S_m, and (a), (b) and (d) in determining R_m. Trials indeed do show that C is proportional to a function of S_m, R_m, suitably weighted as $S_m^{1.5}R_m$, and a plot of $S - S_m$ against $(R - 0.9\ R_m)/S_m^{1.2}\,R_m^{0.8}$ on a log-log graph approximates closely to a *unique straight line* for all the cases of fractionation considered. The slope of this line is, of course, still 0.75. Other values of abscissa and ordinate may be obtained by algebraic re-arrangement of the terms, but the ones selected seem to be the most convenient.

Applicability of Correlation. As already indicated, in the main, only one type of fractionation was used in developing the correlation. The applicability of equation 1 may, therefore, be somewhat limited. However, checks show fair agreement with the general correlation of Gilliland,[7] and it is considered that the use of the straight line of Figure 1, in conjunction with the check point technique, should be of general application.

Using the correlation, the deviation from rigorous calculation corresponds generally to a maximum of about 15% in the value of S; the deviation is much less for "normal" separations, i.e. separation with systems not having very high or very low key component ratios in the feed nor a high number of components distributed between top and bottoms product.

About the Author

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Nomenclature

R = Reflux ratio
R_m = minimum reflux ratio
S = number of theoretical steps from reboiler to overhead product
S_m = minimum number of steps at *total* reflux

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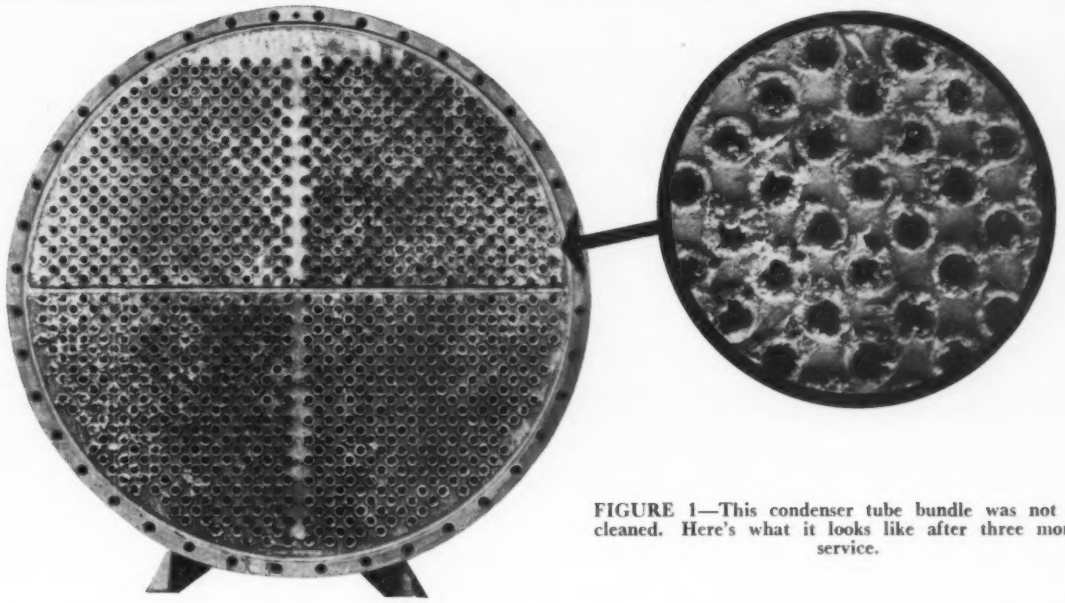


FIGURE 1—This condenser tube bundle was not precleaned. Here's what it looks like after three months' service.

Follow new startup procedure to . . .

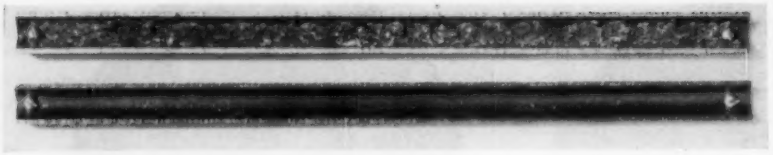
Reduce Cooling System Corrosion

Fabrication oil films on steel tubes interfere with inhibitor adsorption. Precleaning and week-long inhibitor circulation is essential to prevent corrosion

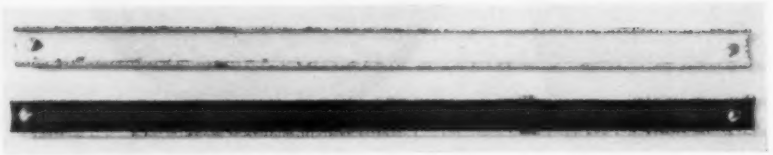
C. T. Palen
Shell Oil Company
Wilmington, California

IN RECENT YEARS improvements in corrosion inhibitors and pH control systems have led to the increased use of steel tubes for condensers and coolers in industrial cooling water systems. The satisfactory application of steel for this service in place of the more expensive copper alloys results in substantial savings in plant capital investment. Also, in many cases steel tubes permit the use of ammonia for the neutralization of acidic materials present in the process stream being cooled, while brass tubes are subject to attack by ammonia. In several instances, however, the use of accepted water treating procedures in newly constructed plants has been attended by severe waterside corrosion and fouling by the corrosion products during the first few weeks or months of operation. Figure 1 shows a condenser removed from a new plant at the Wilmington Refinery of Shell Oil Company after less than three months operation. Other refineries have reported similar rates of

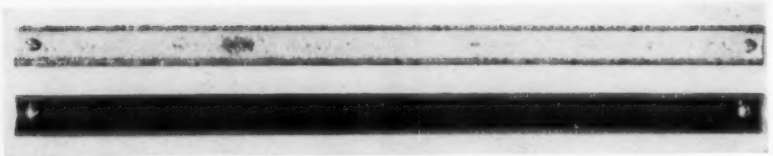
Reduce Cooling System Corrosion . . .



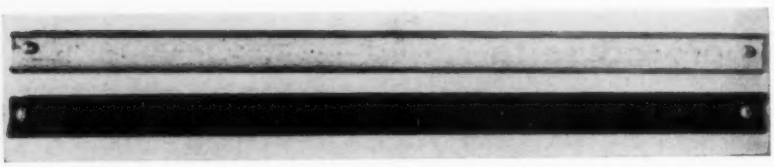
NO PRE-TREATMENT



HOT DETERGENT SOAK + SANDBLAST



HOT DETERGENT SOAK + SANDBLAST + COLD INHIBITOR SOAK



HOT DETERGENT SOAK + COLD INHIBITOR SOAK

FIGURE 2—Tubes look like this after four months' service. After splitting, lower half of tubes were wire-brushed to show condition of surface.

attack. In these cases the corrosion was reduced to acceptable levels by cleaning the tubes and usually making some change in treatment procedure, i.e., in inhibitor or in method of slime control, etc. However, the causes of the initial high rates of attack were not completely explained.

It has been suspected the oily films left on new tubes as a result of fabrication and assembly operation may interfere with the uniform adsorption of inhibitor on the tube surfaces when the heat exchanger is first placed in service. This hypothesis has been confirmed in tests employing the two most widely used types of inhibitors. These are chromate or phosphate, blended with other materials for increased effectiveness.

Test Procedure. Test 1 was made with a new condenser bundle in a system using a phosphate-base inhibitor in the circulating water at the normal 25 ppm phosphate concentration. The condenser was given a preservice cleaning by soaking in hot detergent for 3 hours at 180 F. followed by sandblasting. It was then soaked overnight in a strong solution of the inhibitor containing 1,000 ppm phosphate to establish the protective film just before placing the condenser in service. Test specimen tubes were sealed off at appropriate stages of the cleaning and inhibitor-soaking treatment to show the effects of:

1. No pretreatment
2. Hot detergent soak plus sandblast
3. Hot detergent soak plus sandblast

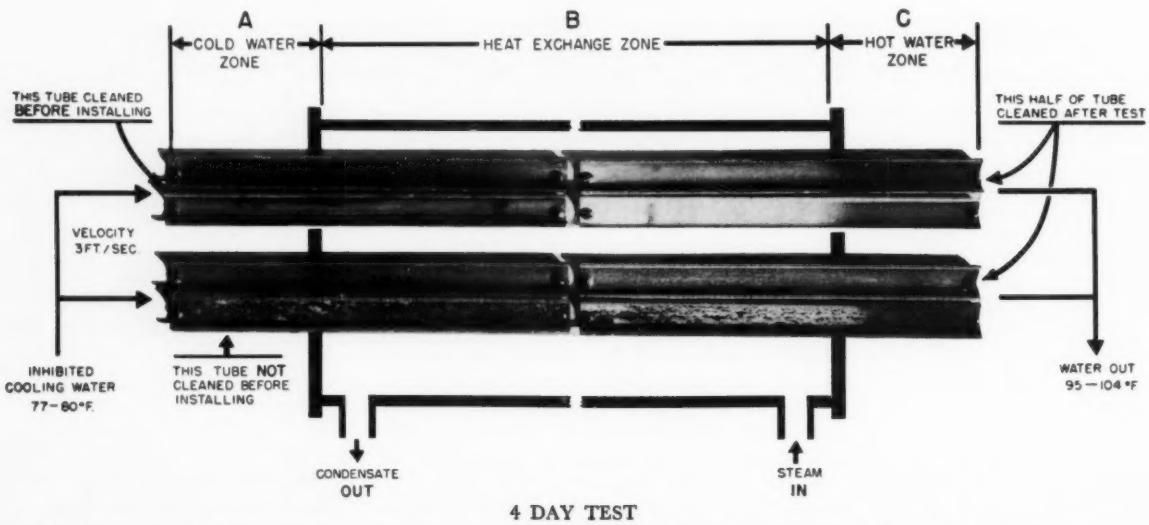


FIGURE 3—In this test, tubes were extended three inches beyond exchanger shell to observe difference in corrosion rates.

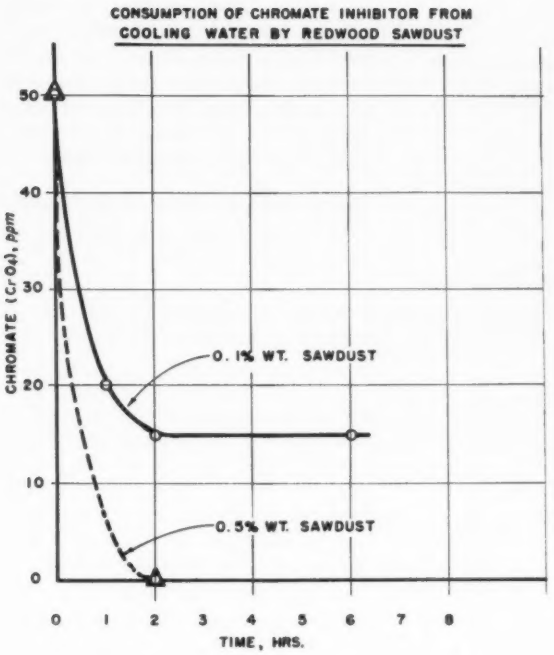


FIGURE 4—(left) New redwood towers consume inhibitor during startup.

FIGURE 5—(above) Temporary screen collects large amount of redwood sawdust and fiber from tower during initial circulation.

plus strong cold inhibitor soak

4. Hot detergent soak plus strong cold inhibitor soak

Test Results. Tests were run in quadruplicate. Figure 2 shows the marked difference in the tubes after four months service. The lower half of each tube was wire-brushed after cutting open to show the condition of the metal surface. Tubes which had received no preservice cleaning were heavily fouled with reddish brown corrosion products which covered numerous pits and corroded areas. All other tubes had a thin gray deposit under which corrosion was negligible.

In Test 2 similar results were obtained in another system using a chromate-base inhibitor. In this case, a pilot condenser was installed using the plant cooling water with chromate level at 40-50 ppm (twice normal concentration) as recommended for new tubes. Duplicate tubes were cleaned by sandblasting and compared with tubes placed in service without precleaning. As shown in Figure 3 the tubes were extended 3 inches beyond the ends of the condenser shell to observe any differences in corrosion rates in the cold water, heat exchange, and hot water zones. After a four-day test the tubes precleaned by sandblasting showed no visible corrosion while those which had not been precleaned exhibited substantial pitting and fouling by corrosion products. As might be expected, pitting was more severe in the heat exchange zone than in either the hot water or cold water zones where lower tube wall temperatures prevail.

It has thus been established that the precleaning of new steel condensers and coolers is essential if the maximum effectiveness of inhibitors is to be obtained.

Other factors peculiar to the start-up of new cooling systems may also impair inhibitor functioning. Some of these, for which laboratory test data were obtained, are:

1. Soluble redwood extract, leached from the new cooling tower lumber during early circulation, reacts with chromate inhibitor.

Test Data	CrO_4, ppm
Inhibited Water	19.3
Inhibited Water plus Equal Volume Wash Water from new Cooling Tower	12.0 (basis orig. vol.) 7.3

2. By yielding soluble extract, small amounts of wood fiber and sawdust washed from a new tower may become lodged in the tubes under stagnant water conditions and reduce local inhibitor concentration at tube surfaces. The following test data, which is plotted in Figure 4 shows that consumption of inhibitor by the new wood fiber is quite rapid.

The wood "fill" slats in cooling towers are rough cut to provide maximum breakup of falling water droplets, and when new, are a source of loose fibers and sawdust. In the recent startup of a new 13,000 gpm tower, fine 18-mesh screens were attached temporarily on the downstream side of the permanent suction screens (having 3/16 inch openings) at the basin outlets. These fine screens became plugged with wood fibers and sawdust within 10-15 minutes after circulating was started. This rate of fiber removal continued for several hours and then diminished. Figure 5 shows one of the 3 feet by 5 feet screens when removed for cleaning the third time.

If this fiber enters the cooling system it may, by shielding the tube surfaces from the inhibitor, accelerate corrosion through the formation of concentration cells.

3. Inhibitor in cooling water is depleted rapidly by new steel tubes while the inhibiting film is being formed. It is important that an adequate supply of inhibitor be main-

Test Data				
Test 1—**Redwood Sawdust Concentration: 0.5 Percent Weight**				
Contact time, hrs	0		2	
Chromate remaining, CrO_4, ppm	50		0	
Test 2—**Redwood Sawdust Concentration: 0.1 Percent Weight**				
Contact time, hrs	0	1	2	6
Chromate remaining, CrO_4, ppm	50	20	15	15

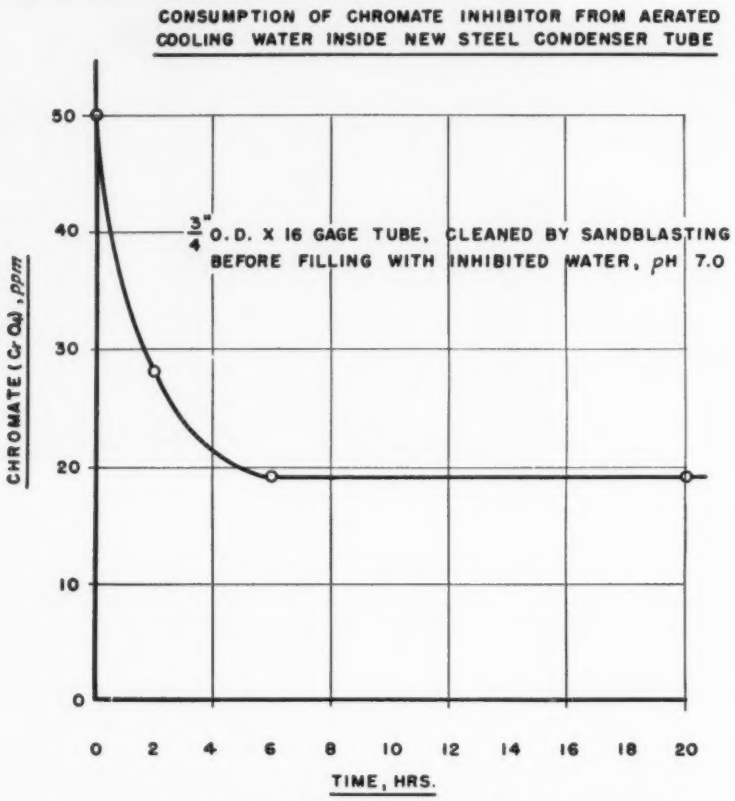

CONSUMPTION OF CHROMATE INHIBITOR FROM AERATED COOLING WATER INSIDE NEW STEEL CONDENSER TUBE
3/4" O.D. X 16 GAGE TUBE, CLEANED BY SANDBLASTING BEFORE FILLING WITH INHIBITED WATER, pH 7.0
CHROMATE (Cr O4), ppm
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20
TIME, HRS.

FIGURE 6—Inhibitor is depleted rapidly while film is being formed.

About the Author

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tained continuously at the tube surface during this period. The following data which are plotted in Figure 6, show the rate of inhibitor consumption from preaerated water by new clean steel condenser tubes under stagnant conditions.

Test Data		
Tube No.	Contact Time, Hrs.	Chromate Remaining, CrO_4, ppm
*	0	50
1	2	28
2	6	19
3	20	19

* Original solution.

It is evident that under no-flow conditions critical depletion of inhibitor in new tubes may occur within a few hours. The water volume within the tubes is only approximately 2 percent of the total water volume in a typical system. Hence, complete loss of inhibitor in stagnant tubes during a pause in initial circulation would not be noted by inhibitor residual determinations made after flow was resumed. It is therefore considered essential that flow, once started, be maintained without interruption until the inhibiting film has been formed. Minimum time required to establish the film has not been determined, but may require several days to perhaps a week.

TESTS REVEAL NEW PROCEDURE

From these tests it is evident that placing a new cooling system in operation should include several procedures that have not heretofore been considered standard practice. These are:

1. Circulate tower initially for several days through a bypass connection between the supply and return water headers, leaving the condensers blocked to flow. This serves a dual purpose: (a) It washes the tower of loose wood fibers and sawdust, and (b) permits the "running in" of circulating pumps and pH control equipment so that positive flow of properly treated water may be maintained after the plant is placed on-stream. A portion of the soluble redwood extract will be removed during this period, but experience indicates that leaching occurs for several weeks. If construction schedules permit completion of the cooling tower ahead of the remainder of the plant, lawn-type sprinklers may be installed temporarily in the top of the tower in order to leach most of the redwood extract before initial circulation is started.

2. Provide temporary fine screens (approximately 18 mesh/in) at basin outlets to trap wood fibers removed from the initial circulation of tower.

3. Clean thoroughly all steel-tubed condensers and coolers of oily films before exposing to flow of aerated cooling water.

4. After placing the plant on stream, maintain normal flow rates of inhibited water without interruption for approximately one week.

The use of the above procedures requires the coordinated planning of the construction, operating and utility groups concerned with starting a new plant. However, they permit the removal, before the plant is placed on stream, of materials from the cooling system which are deleterious to corrosion control. Presenting clean tube surfaces to the circulating water will result in the uniform adsorption of inhibitor which in turn will provide the satisfactory corrosion control which is possible with present cooling water inhibitors. ##

Quickly Estimate Steam Plant Costs

These factors permit rapid estimation of large steam generating unit costs

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APPROXIMATELY $15 billion will be spent for steam generating facilities by 1960. In the face of such growth (estimated capital expenditures for new plants and equipment during the next ten years is over $250 billion), the extent to which cost should influence the selection of steam generating plants is an industry-wide problem. Since there is a lack of published data covering the unit costs of the major equipment items comprising a modern steam generating plant, factors are presented here for estimating these costs for the usual types of steam plants encountered in industry.

Seasonal Versus Base-Load. The extent to which costs influence the selection of steam generating units can only be ascertained through an analysis of both initial investment and operating costs. For example, a steam plant located near an ample supply of low-priced fuel, and having a seasonal load during only 3 or 4 months of the year, presents a condition entirely different from that of a base-load steam plant with a load factor approaching 100 percent and burning a high-priced fuel.

The unit for the first set of conditions would include a standard type boiler, all-refractory furnace, no heat recovery equipment, and a natural draft chimney.

In contrast, the conditions that characterize the base-load unit will justify a capital investment sufficient to provide a highly efficient fuel-burning system, water cooled furnace walls, high pressure boiler, high temperature superheater, heat recovery equipment, induced draft fan, and a major refinement of auxiliaries.

The latter set of conditions usually prevail in industry and the cost factors presented apply to this type of equipment.

Other Factors. There are many factors other than cost which influence both the type of fuel used and type of steam generating equipment. These include fuel characteristics, steam requirement and operating conditions, space limitations and personal preference. The value of the first four items can readily be evaluated and become important factors in the final selection of the type of equipment to be adopted. A well-founded individual preference should also be respected and given full consideration. However, mere personal prejudice should be eliminated so that it does not jeopardize the value of an investment for any plant expansion or modification.

It is extremely difficult to prepare general cost data that may be uniformly applied to widely varied situations because of the many variables which may necessitate major alterations to basic deign in order to provide a unit best suited to the specific conditions. In addition, no group of tables or cost curves can provide a satisfactory shortcut to equipment selection. Final decisions in this important matter should always reflect the judgment of competent engineers who specialize in this field. As a guide, however, carefully prepared data have been used to plot the curves in Figures 1, 2, 3 and 4. These show the relation between cost and capacity of the major component items comprising a modern steam generating plant. No attempt has been made to provide similar data for units below 100,000 pounds of steam per hour capacity, due to the wide variety of designs available

and many difficult conditions of installation that are commonly encountered.

Type of Fuel. The basic types of steam plants can be characterized by the type of fuel used. The principal fuels used today are coal, natural or refinery gas, and oil. Most plants are designed to use a combination of these fuels to enable the plant to be shifted quickly from one of several fuels to another, to take advantage of any favorable price differential or supply conditions that may occur from time to time. The more common combinations are: (1) natural or refinery gas with oil stand-by, (2) pulverized coal with oil standby, and (3) stoker fired with oil stand-by. The costs for different fuel combinations will vary markedly due to the necessity of designing a unit for specific steam conditions with increased restrictions on internal arrangement and materials of construction.

Boiler Construction Trends. Cost data for steam generating units employing these three basic types of fuel combination are presented in Figures 1, 2 and 3, respectively.[1] These costs do not include the primary feed water treating and fuel storage facilities. The following comments are important in interpreting the data presented in these curves.

The present trend in boiler construction shows that the vertical bent tube type consisting of an upper steam drum and a lower mud drum is widely accepted with increasing use of shop fabricated water wall sections. The furnace is completely water cooled on the roof and sides. Units employing gaseous and pulverized fuels have additional water tubes for cooling the furnace floor. The heat recovery equipment includes both economizer and air heaters to obtain the highest efficiency which can be economically justified.

The economizer is additional heating surface of the continuous loop, single element type located in the path of the exit boiler gases. The boiler feedwater is pumped through the economizer instead of directly to the boiler to increase the unit heat efficiency.

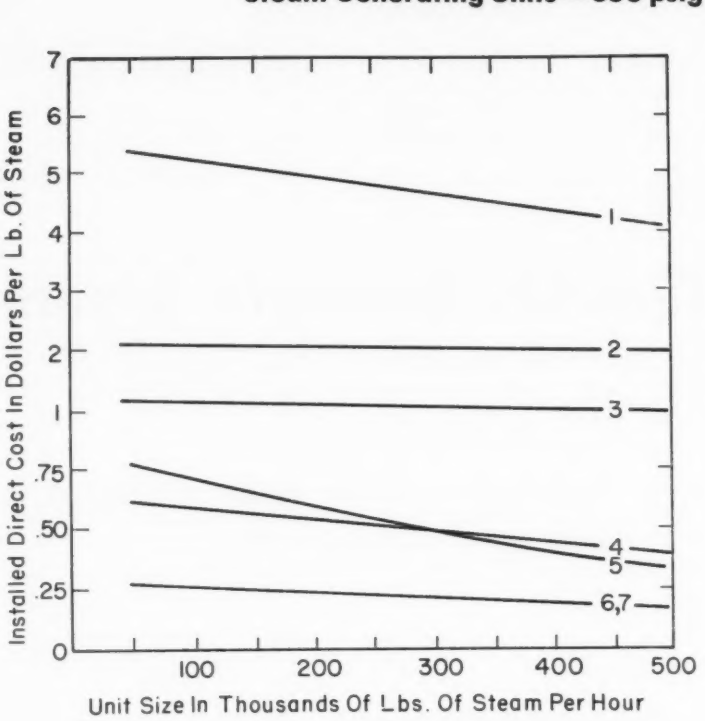
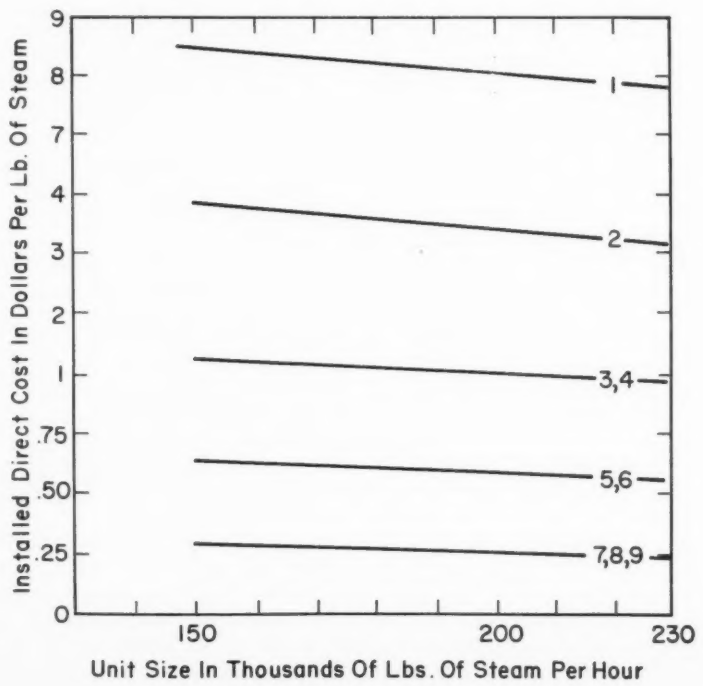


FIGURE 1—(above) Gas fired with oil standby boilers have these direct costs. Code: 1—Total; 2—Boiler; 3—Piping; 4—Building; 5—Instrumentation; 6—Fans/Drive—I.D. & F.D.; 7—Boiler feed pump and chemical treatment.

FIGURE 3—(below) Stoker fired with oil standby boilers have these direct costs. Code: 1—Total; 2—Boiler; 3—Coal handling; 4—Piping; 5—Building; 6—Instrumentation; 7—Ash handling; 8—Fans/Drive—I.D. & F.D.; 9—Boiler feed pump and chemical treatment.



at 750 F. Total Temperature . . .

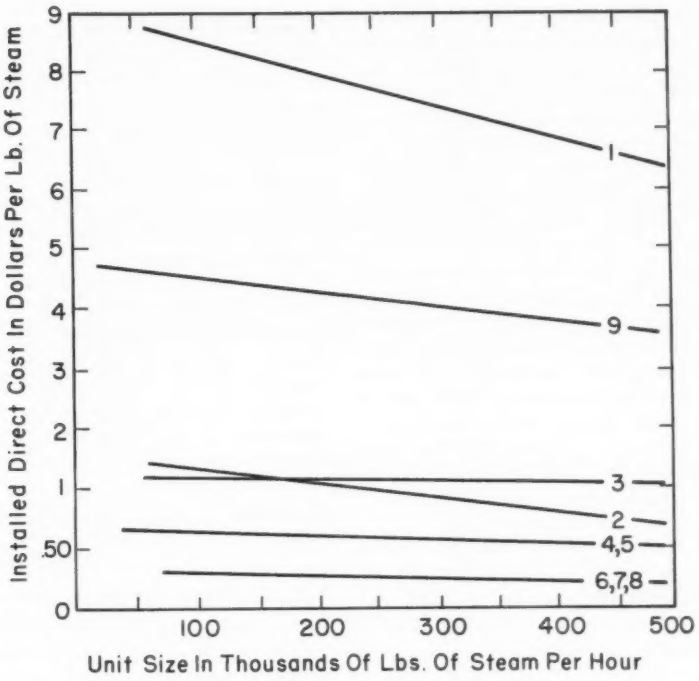
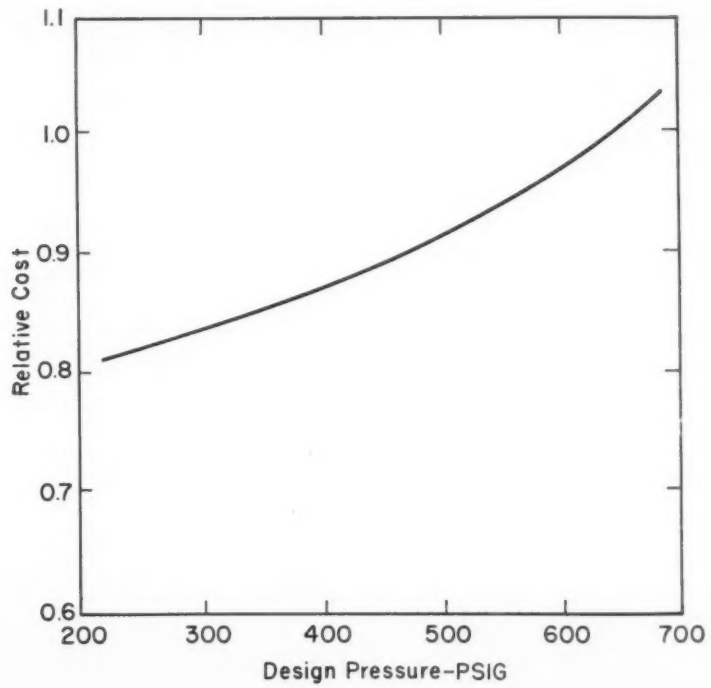


FIGURE 2—(above) Pulverized coal fired with oil standby boilers have these direct costs. Code: 1—Total; 2—Coal handling; 3—Piping; 4—Building; 5—Instrumentation; 6—Fans/Drive—I.D. & F.D.; 7—Ash handling; 8—Boiler feed pump and chemical treatment; 9—Boiler.

FIGURE 4—(below) For pressures other than 650 psig, but at the same capacity, use these correction factors to arrive at total boiler costs.



The air heater, for boiler capacities up to 200,000 pounds per hour steam, is the tubular type arranged in a vertical bank with the air making two passes over the elements. Above this level, the regenerative type is employed.

The regenerative type air heater has a large amount of steel plate surface which is alternately heated by the flue gases and cooled by the air. This is accomplished by continually revolving the plate surface through the gas and air stream. Space arrangement and quantity of dust in the gases are the primary factors to be considered in the selection of air heaters. The tubular type required more space but is not easily plugged with flue gas dust.

A large amount of superheater surface is provided by using a convection inter-bank type, vertically hung and having a high percentage of alloy material. Also included in the boiler costs are burners arranged for simultaneous or alternate firing of the fuel and manually operated soot blowers. Although pressurized furnace boilers for oil and gas firing are increasing in popularity due to lower costs and greater compactness, all cost data have been prepared based on the use of conventional field erected units with forced and induced draft fans to remove the gases of combustion from the boiler unit. These fans are the double inlet, centrifugal type, of heavy duty construction and driven through speed reducers by an impulse, two row element steam turbine. The forced draft fans are generally the backward curved blade type rotating within a spiral or volute housing. Induced draft fans for moderate pressures, are generally the forward curved blade type. For higher pressures, straight blade or radial tip fans are employed.

Fuel Handling. The fuel handling equipment for the pulverized and stoker fired units consist of conveyors for transporting the coal from the storage area to the boiler house and distribution to the separate coal bunkers for each boiler. For oil fired plants, the fuel handling equipment consists of a fuel oil pumping unit and oil heaters. Gas fired units re-

About the Authors

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quire no fuel handling facilities other than a tie-in to the main gas main through a pressure regulating valve. However, where different fuel combinations are used, facilities must be provided for effective handling of both fuel types. Ash handling equipment for the coal fired units consists of the conventional water sluiceway system.

The coal pulverizer is the ball mill type equipped with mill drying. A classifier is located above the grinding chamber with its outlet connected to the mill exhauster. The entire mill assembly is suitably enclosed in a welded steel housing. A rotary feeder is employed to feed the coal to the pulverizer. The fine coal is removed from the classifier by the mill exhauster through the top central outlet and discharged through the connecting fuel lines and burners into the furnace. The stoker employed is the conventional continuous spreader type with the grate moving to the front. The coal is fed from a hopper and the refuse is discharged into a pit located at the stoker front. A continuous discharge type stoker will allow a narrower boiler unit to be used which usually results in a considerable reduction in first costs. In addition, it allows a wider range of fuels to be employed.

Instrumentation. Reliable instruments that indicate and record the principal operating data are required to attain the highest possible efficiency and continuity of operation in any steam generating plant. These instruments are mounted on a control panel conveniently located in the boiler control room. In addition to the necessary instruments, a fuel-air flow proportioning system for combustion control and a three element feed water control system are installed on the panel and are readily accessible. Usually for pulverized coal and always on stoker fired units, a steam-air flow proportioning system is used. A high degree of instrumentation can be justified to secure increased efficiency through close combustion control and continuous monitoring of the operating conditions. The cost of boiler instrumentation and automatic combustion controls increases slightly with boiler capacity since, with large boilers, larger metering and control valve equipment are needed. In addition, larger boilers usually are supplied with more extensive metering equipment.

Type of Construction. A semi-outdoor type of building is employed and, together with the equipment, is supported on 15 ton concrete piles. The boiler firing aisle is enclosed in a masonry type structure while the control room and offices have finished interior walls. All exposed structural steel is galvanized. The piping required within the battery limits is prefabricated from carbon steel, ASTM Specification A-106 pipe. The boiler feed pumps employ a cast steel body with allow trim and are driven with a mechanical steam turbine. A standard tray type deaerator is also included with a capacity equal to the boiler capacity.

Example: A typical example is included to illustrate the use of the cost curves in estimating steam generating units costs. The boiler shall have a maximum continuous capacity of 400,000 pounds per hour at 650 psig superheater outlet pressure and 750 FTT steam temperature, when supplied with feedwater of 250 FTT and fired by natural gas or oil. The unit costs obtained from Figure 1 are as follows:

Boiler:	400,000 lbs/hr × $2.05/lbs Steam	= $	820,000
Piping:	400,000 lbs/hr × $1.05/lbs Steam	=	420,000
Building:	400,000 lbs/hr × $0.44/lbs Steam	=	176,000
Instrumentation:	400,000 lbs/hr × $0.40/lbs Steam	=	160,000
Fans and Drives:	400,000 lbs/hr × $0.18/lbs Steam	=	72,000
Boiler Feed Pumps and Chemical Treatment	400,000 lbs/hr × $0.18/lbs Steam	=	72,000
Total Direct Installed Cost		=	$1,720,000

These costs can be corrected to other boiler pressures by multiplying the costs by the appropriate correction factor shown in Figure 4.[2] For example, the cost of the same unit designed for 250 psig operating pressure would be: $1,720,000 × 0.825 = $1,419,000 where the factor 0.825 is the relative cost of a 250 psig unit. No costs are included for overheads and contingencies since these will vary with each company and location.

ACKNOWLEDGMENT

The authors are grateful to The Chemstrand Corporation for permission to publish this manuscript and to A. W. Gentry for his helpful suggestions and criticisms.

LITERATURE CITED

[1] Private correspondence with Combustion Engineering, Inc. and Babcock and Wilcox Co.
[2] "Combustion Engineering," Riverside Press, P 24.22 (1947)

Compute Distillation Trays Rapidly

- New
- Fast
- Easy

Alfred J. Surowiec
Maplewood, N. J.

A SIMPLE RELATION is developed here which may be used for rapid estimation of the number of trays in multicomponent distillation. The method, using the log mean composition change, gives results with an accuracy of 5 to 10 percent of the true number of trays.

The cumbersome recurrence relations encountered in multicomponent distillation have left the designer with a need for a rapid means of estimating tray requirements for such systems. A differential equation might at first appear to add to the complexity of an already difficult subject but with suitable modifications it can be used as a way of proceeding directly to the desired result.

The basic relations of multicomponent distillation are well known[1] and will not be repeated here. It is convenient to put the operating equation in the same form as the equilibrium relationship and introduce a composition ratio ϕ such that[2]

$$\phi_n = \frac{Y_{n+1}}{X_n} \tag{1}$$

Combined with the equilibrium equation

$$\alpha_n = \frac{Y_n}{X_n} \tag{2}$$

there results the recurrence relations

$$\frac{\alpha_n}{\phi_n} = \frac{Y_n}{Y_{n+1}} \tag{3a}$$

$$\frac{\alpha_{n+1}}{\phi_n} = \frac{X_n}{X_{n+1}} \tag{3b}$$

Counting down from the top of the tower

$$\frac{\alpha_1}{\phi_1} \cdot \frac{\alpha_2}{\phi_2} \cdot \cdots \frac{\alpha_n}{\phi_n} = \frac{Y_1}{Y_{n+1}} \tag{4a}$$

$$\frac{\alpha_1}{\phi_0} \cdot \frac{\alpha_2}{\phi_1} \cdot \cdots \frac{\alpha_n}{\phi_{n-1}} = \frac{X_0}{X_n} \tag{4b}$$

In logarithmic form

$$\log Y_1 - \log Y_{n+1} = \sum_{q=1}^{n} \log \frac{\alpha_q}{\phi_q} \tag{5a}$$

$$\log X_0 - \log X_n = \sum_{q=1}^{n} \log \frac{\alpha_q}{\phi_{q-1}} \tag{5b}$$

The summation terms appearing on the right side of equations (5) represent areas beneath step curves composed of rectangles of heights equal to $\log \frac{\phi_q}{\alpha_q}$ and $\log \alpha_q/\phi_{q-1}$, and widths of unity. The areas beneath the step curves can be approximated in the following manner by the familiar trapezoidal rule

$$\int_0^n \log \frac{\alpha_n}{\phi_n}\, dn = \sum_{q=1}^{n} \frac{1}{2}\left(\log \frac{\alpha_q}{\phi_q} + \log \frac{\alpha_{q-1}}{\phi_{q-1}} \right)$$

$$= \sum_{q=1}^{n} \log \frac{\alpha_q}{\phi_q} - \sum_{q=1}^{n} \frac{1}{2}\left(\log \frac{\alpha_q}{\phi_q} - \log \frac{\alpha_{q-1}}{\phi_{q-1}} \right) \tag{6a}$$

$$\int_0^n \log \frac{\alpha_{n+1}}{\phi_n}\, dn = \sum_{q=1}^{n} \frac{1}{2}\left(\log \frac{\alpha_{q-1}}{\phi_q} + \log \frac{\alpha_q}{\phi_{q-1}} \right)$$

$$= \sum_{q=1}^{n} \log \frac{\alpha_q}{\phi_{q-1}} + \sum_{q=1}^{n} \frac{1}{2}\left(\log \frac{\alpha_{q+1}}{\phi_q} - \log \frac{\alpha_q}{\phi_{q-1}} \right) \tag{6b}$$

Introducing the above into equation (5),

$$\log \frac{Y_1}{Y_{n+1}} = \int_0^n \log \frac{\alpha_n}{\phi_n}\, dn + \frac{1}{2}\left(\log \frac{\alpha_n}{\phi_n} - \log \frac{\alpha_0}{\phi_0} \right) \tag{7a}$$

$$\log \frac{X_1}{X_n} = \int_0^n \log \frac{\alpha_{n+1}}{\phi_n}\, dn - \frac{1}{2}\left(\log \frac{\alpha_{n+1}}{\phi_n} - \log \frac{\alpha_1}{\phi_0} \right) \tag{7b}$$

Differentiation of (7) yields

$$-\log\left(\frac{Y_n}{Y_{n+1}}\right) dn = d \log Y_{n+1} + \frac{1}{2}\, d \log \frac{Y_n}{Y_{n+1}} \tag{8a}$$

$$-\log\left(\frac{X_n}{X_{n+1}}\right) dn = d \log X_n - \frac{1}{2}\, d \log \frac{X_n}{X_{n+1}} \tag{8b}$$

If the equilibrium relationship had been written in terms of the equilibrium constant

$$K_n = \frac{y_n}{x_n} \qquad (9)$$

there would be the pair of useful equations

$$-\log\left(\frac{y_n}{y_{n+1}}\right) dn = d\log y_{n+1} + \frac{1}{2} d\log\frac{y_n}{y_{n+1}} \qquad (10a)$$

$$-\log\left(\frac{x_n}{x_{n+1}}\right) dn = d\log x_n - \frac{1}{2} d\log\frac{x_n}{x_{n+1}} \qquad (10b)$$

Equations (8) and (10) are not exact relations, but very useful approximations. They have an accuracy of 1 percent for large values of α and K, while for large values of n the trapezoidal approximation improves and the equations tend to become more exact.

As a means of making a rapid design estimate with an accuracy of 5 to 10 percent, a linear approximation can be made to permit analytical integration of the equations: $\log\frac{Y_n}{Y_{n+1}}$ and $\log\frac{X_n}{X_{n+1}}$ can be taken linear in $\log Y_{n+1}$ and $\log X_n$, and $\log\frac{y_n}{y_{n+1}}$ and $\log\frac{x_n}{x_{n+1}}$ can be taken linear in $\log y_{n+1}$ and $\log x_n$, respectively. For example

$$-dn = \left(\frac{\Delta\log Y_{n+1}}{\Delta\log\frac{Y_n}{Y_{n+1}}} + \frac{1}{2}\right)\frac{d\log\frac{Y_n}{Y_{n+1}}}{\log\frac{Y_n}{Y_{n+1}}} \qquad (11)$$

$$-\Delta n\left(\frac{\Delta\log\frac{Y_n}{Y_{n+1}}}{\Delta\log\log\frac{Y_n}{Y_{n+1}}}\right) = \Delta\log Y_{n+1} + \frac{1}{2}\Delta\log\frac{Y_n}{Y_{n+1}} \qquad (12)$$

In the above, X_n/Y_{n+1} can be taken equal to unity at the top and bottom of a tower and a single theoretical tray can be allowed for a partial condenser or equilibrium reboiler. Equation (12) holds for either the enriching or stripping section of a tower and requires a feed plate match before it can be applied to the over-all tower.

About the Author

Alfred J. Surowiec is a professional consulting engineer at Maplewood, N.J. After receiving a B.S. degree in chemical engineering from Newark College of Engineering and a M.S. degree in chemical engineering from Yale University, he joined Cities Service Refining Corp. as a process engineer in 1943. From 1950-54 he was a process engineer for Catalytic Construction Co., and from 1954-56 was with Westinghouse Corp. as a senior scientist working on commercial atomic power and the chemical processing of nuclear fuels. In 1956 he joined Foster Wheeler Corp. as a group leader, and entered consulting engineering in 1958.

As a test of the linear approximation, consider the binary system with the following properties.

$\alpha = 2$ Reflux to Product
$x_o = y_1 = 0.8$ Ratio = 1

Computing the compositions in the rectifying section by means of the equation of Stoppel[3]

$$\frac{x_o - \bar{x}_o}{\bar{x}_1 - x_o} = \left[\frac{1 + (\alpha - 1)\bar{x}_1}{1 + (\alpha - 1)\bar{x}_o}\right]^n \left(\frac{x_n - \bar{x}_o}{\bar{x}_1 - x_n}\right) \qquad (13)$$

where $\bar{x}_1$ and $\bar{x}_o$ are the intersections of the operating line and the equilibrium curve, and determining the number of trays from equation (12), the following results are obtained:

Actual Trays	Calculated Trays
0.25	0.244
0.50	0.518
1.00	1.03
10.00	10.5
100.00	106.8

For multicomponent systems, consider the rectifying section of the following three component problem:

Comp.	α	$y_o = y_1$	Reflux to Product Ratio = 2
1	3	0.331	
2	2	0.603	
3	1	0.067	

Determining compositions by a tray to tray computation and then calculating the number of trays from equation (12) gives the following results:

Actual Trays	Calculated Trays	
	Comp. 1 & 3	Comp. 2 & 3
1	1.00	1.01
2	2.01	1.97
3	3.00	2.91
4	3.99	3.86
8	8.51	8.62

If Equation (10) is used for this type of computation, then care should be exercised for if the component in question goes through a maximum then $1/\log\frac{y_n}{y_{n+1}}$ will go through infinity and the linear approximation cannot be used. There is less uncertainty when Equation (8) is employed. Use of Equation (10) and the linear approximation in the above problem gave, after 8 actual trays, 9.10 trays for component 1 and 8.21 trays for component 3. Component 2 went through a maximum over the first tray, while component 1 had reached nearly constant compositions after 8 trays.

NOTATION

$K_n = K_{in}$	Equilibrium constant of component i at the tempreature and pressure of plate n.
log	Napierian logarithm.
n	Plate number, counting from the top.
$y_n = y_{in}$	Mole fraction of component i in the vapor leaving plate n.
$x_n = x_{in}$	Mole fraction of component i in the liquid leaving plate n.
$Y_n = Y_{ijn} = y_{in}/y_{jn}$ $X_n = X_{ijn} = x_{in}/x_{jn}$	
$\alpha_n = \alpha_{ijn}$	Relative volatility of component i relative to component j at the temperature and pressure of plate n.
$\phi_n = \phi_{ijn}$	Composition ratio defined by Equation (1).

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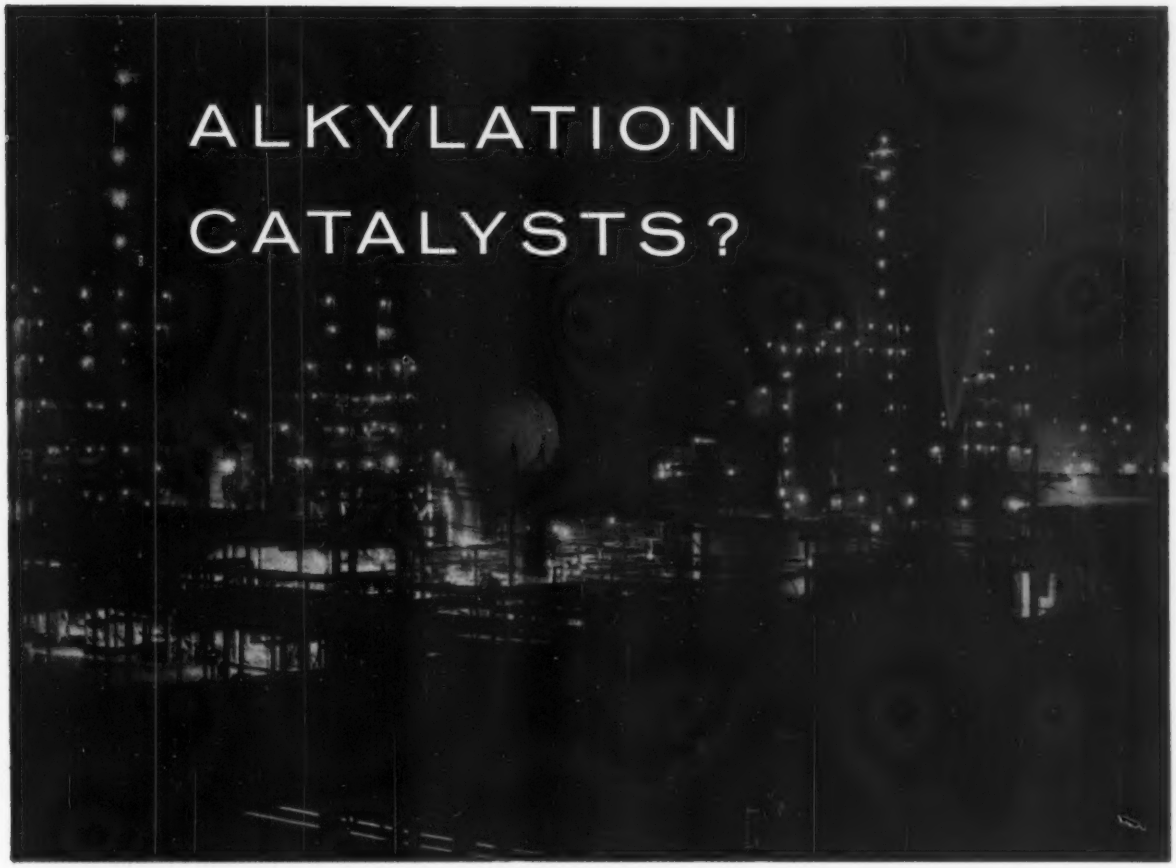
[1] Robinson, C. S., and Gilliland, E. R., "Elements of Fractional Distillation," New York, McGraw-Hill Book Co., 4th Ed., 1950.
[2] Gilliland, E. R., Ind. Eng. Chem., 27, 260 (1935).
[3] Stoppel, A. E., Petroleum Engineer, 18, No. 7, 189 (1947).



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Valuable Reading Ahead

Here's a quick run-down on what's presented in this month's non-technical sections. These departments will keep you right up-to-date with what's new and different in this rapidly changing oil industry.

Man Among Men

The NGAA had just presented the Hanlon Award Citation to its executive vice president, William F. Lowe. You can read about this man who has received one of the Industry's highest honors, plus dozens of "capsule" items on promotions and appointments of other men—many of whom you probably know. Simply . . .

Keep Going to Page 337

You Can Do It

Interested in an easy way to find the weight percent of hydrogen in fuel gas? You can do it by using the handy nomograph in this month's "How To Do It" department. There are also items showing how a six-watt lamp speeds a viscosity index test, how to easily cut tracing paper from a roll, how a pressure-gage needle shuts down a transfer pump, how to make pipe bends with pipe jacks and casters, and how you can make your own tube bundle supports.

Keep Going to Page 252

What's Happening

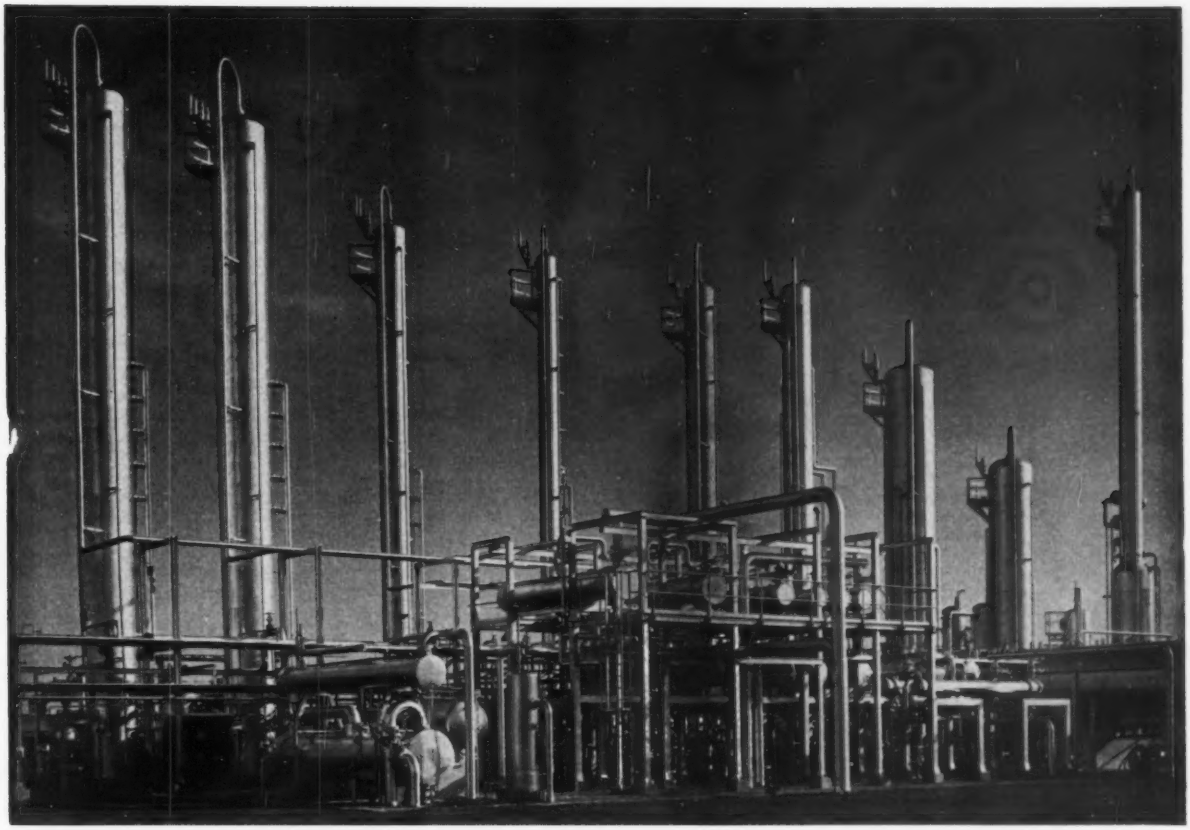
To make sure you're informed of major news developments in the Industry last month, read "What's Happening," a fast moving summary of information about people, places and things in your field. It's just what the doctor ordered for busy men who don't have time to read long accounts of news from their industry. See for yourself!

Keep Going to Page 304

Why Do Employes Quit?

That's an interesting question, but you'll be well along the road to finding the right answers after reading this month's "As Management Sees It . . ." This is the section of PETROLEUM REFINER designed for those in supervisory and managerial positions—and those aspiring to such positions. But back to the employes. One way of finding out why they quit is through the "exit interview." This excellent personnel technique will reach the roots of any "hidden" personnel problems within your organization. It is also a valuable tool in salvaging important employes ready to resign. For the full story of how you can "Find Out Why Employes Quit," be sure you . . .

Keep Going to Page 281



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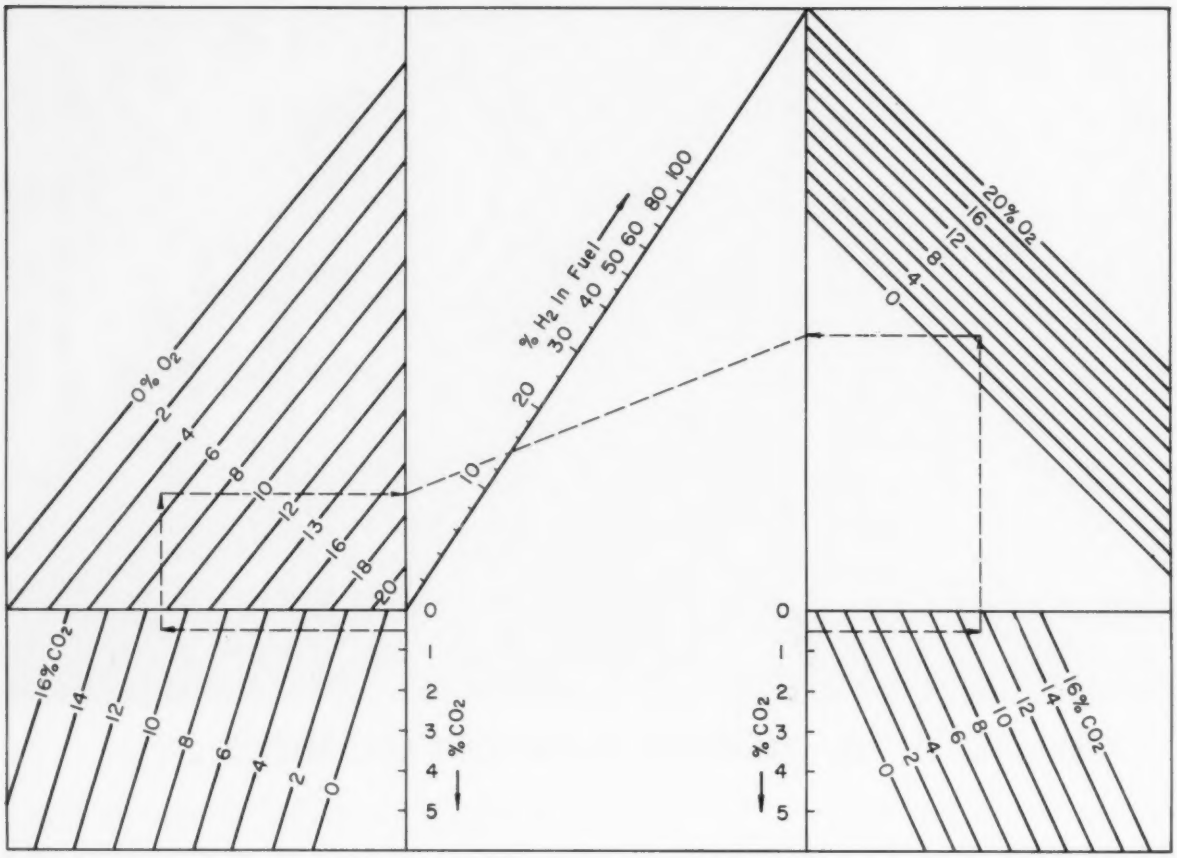


Find Weight of Hydrogen in Fuel Gas

An Orsat analysis will give you the basic information needed to use this handy nomograph

The February, 1959, issue of PETROLEUM REFINER contained a nomograph entitled "Determine Excess Air in Combustion." The above nomograph is a companion to the previously published item.

To find the weight percent of hydrogen in fuel, you need only the Orsat analysis which gives the volume percent of oxygen, carbon monoxide and carbon dioxide in the flue gas.

Example: A flue gas has the following composition:

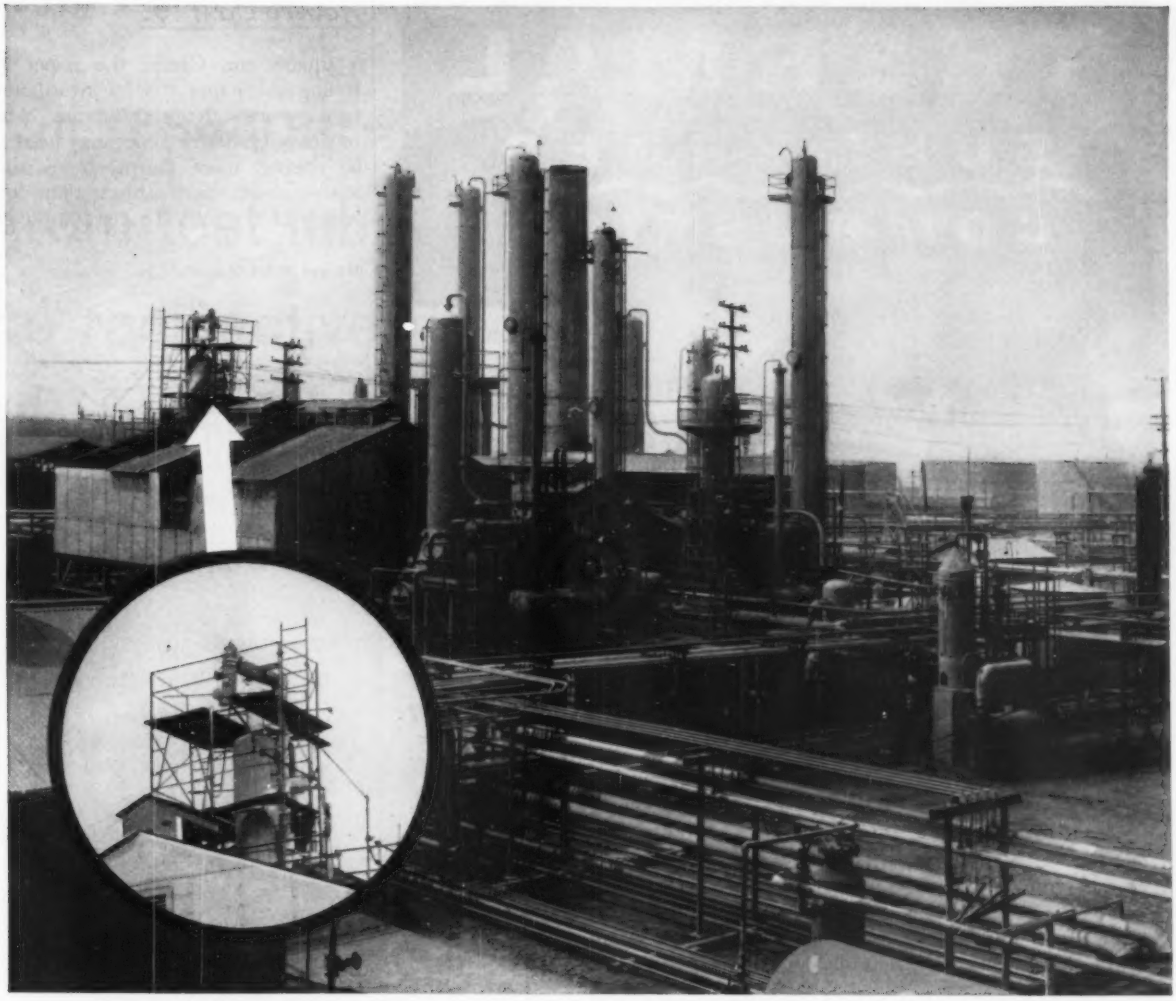
- Carbon monoxide 0.5 percent
- Carbon dioxide 11.0 percent
- Oxygen less 5.0 percent

Follow the segmented lines to find the amount of hydrogen (by weight) equal to 14.2 percent. The calculated result is 14.4 percent.

This idea was submitted by Klaus Lothholz W., Empressa Nacional Del Petroleo, Concon, Chile.

Quick Method for Cutting Tracing Paper From Roll

Need a quick and convenient method of cutting sheets from a roll of drawing paper, tracing paper or tracing cloth? It's easy! Simply unroll the paper to the required width and fold it back on itself as in Figure 2. Align the edges of the sheet to assure



New, nickel-lined butane reactor resists catalyst attack, handles 3500 bbls/day at Shell Oil Company plant, Wilmington, Calif. Pumps, lines, vessels contacting aluminum chloride catalyst are also Nickel.

New reactor boosts butane conversion 18%

...Nickel lining checks catalyst corrosion

Shell Oil Company recently revealed a new butane isomerization reactor that raises yields and reduces equipment requirements. The new reactor boosts conversion of normal butane to isobutane from 51% to about 60%. Shell engineers also estimate that, if designed into a new liquid phase isomerization unit, capital investment costs would be 15% less.

In the Shell process, normal liquid butane is dewatered, heated, scrubbed, fed into the reactor. Here, in contact with a liquid catalyst of aluminum chloride in antimony chloride, it is converted to isobutane.

The reactor has to withstand a highly corrosive combination – hydrogen chloride, metal chlorides, sulfur traces . . . too much for ordinary metals to handle. Shell's designers specified Nickel to check corrosion. The reactor and all pumps, lines and vessels contacting the catalyst are Nickel or nickel-lined to insure against corrosion failure.

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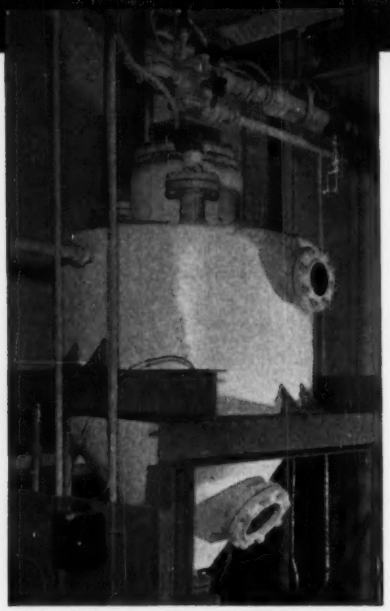

simplicity of

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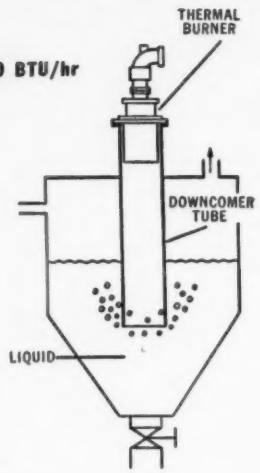
The high heat release rate of the THERMAL High Velocity burner used in these submerged combustion installations allows the use of a simple downcomer tube through which the products of combustion are discharged beneath the surface of the liquid. This arrangement is possible because combustion is 90% completed within the burner proper. The THERMAL burner is completely separate from the liquid being heated and maintenance, control and accessibility are greatly simplified. Equally simple arrangements are possible with gas, oil or combination fuel.



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Depending upon the material being heated either a metal or refractory downcomer tube may be used. Some of the more common applications are pickling baths, acid concentration, caustic soda concentration, aluminum sulphate concentration, water recarbonization, and glass frit and molten salt heating.

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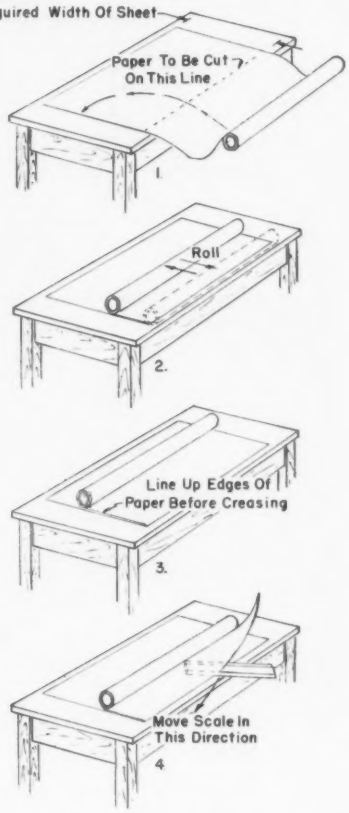
How To Do It . . .

a square cut. Crease the paper by rolling the paper roll backward and forward several times. Tracing cloth or heavy grades of paper may need to be creased more sharply by passing some smooth hard object along the length of the fold. To cut the paper,



hold the roll down firmly with one hand. Insert the edge of a flat draftsman's scale or a metal erasing shield between the folded sheet and draw the scale through the fold in the paper.

A thin blunt edge is best for cutting in this manner, as a sharp knife edge does not always follow the fold in the paper.

This idea was submitted by W. B. Carlin, 627 Moulton St., S.E., Decatur, Ala.

Six-Watt Lamp Speeds Viscosity Index Test

In an oil testing laboratory, the oil sample to be tested is often very opaque and extremely viscous. This can cause considerable difficulty in obtaining proper viscosity index num-

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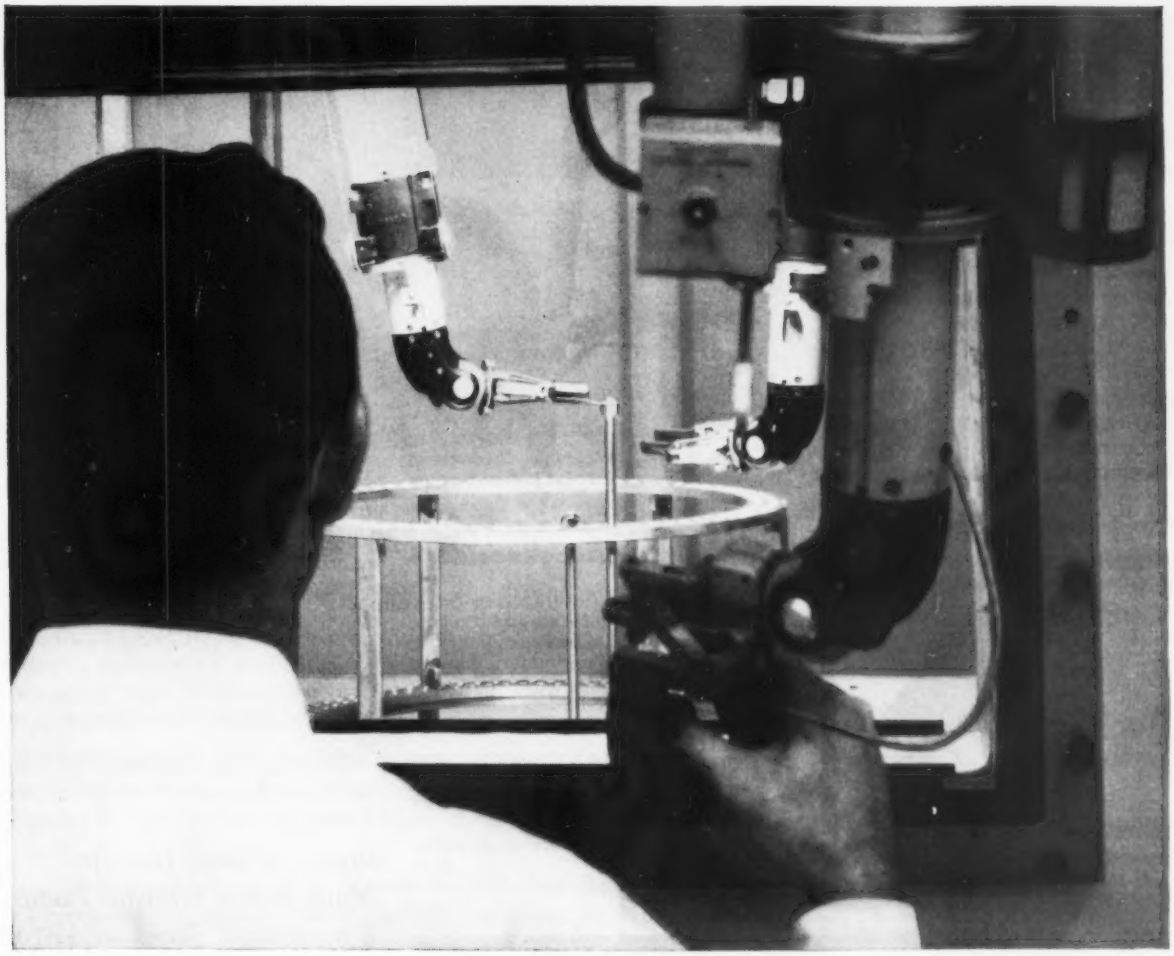
NEWS ON TEXACO PROGRESS—RESEARCH

Oil research—from test tube to radioactive cobalt

YESTERDAY. Decades ago, Texaco scientists worked with relatively crude laboratory equipment, as they probed the fundamental mysteries of oil. Nevertheless — though early oil research was primitive — it resulted in important improvements in petroleum products. Many of these improved products were pioneered by Texaco.



TODAY. Texaco scientists continue their search for basic petroleum knowledge, now using such ultramodern tools as radioactive Cobalt-60 in one of the world's most fully-equipped industrial research laboratories. This is only part of Texaco's great research center at Beacon, N. Y., one of the Company's four modern research centers. Hundreds of Texaco scientists are continually working to create new and better products for more and more people.

TEXACO

...CONSTANT PROGRESS IN OIL'S FIRST CENTURY

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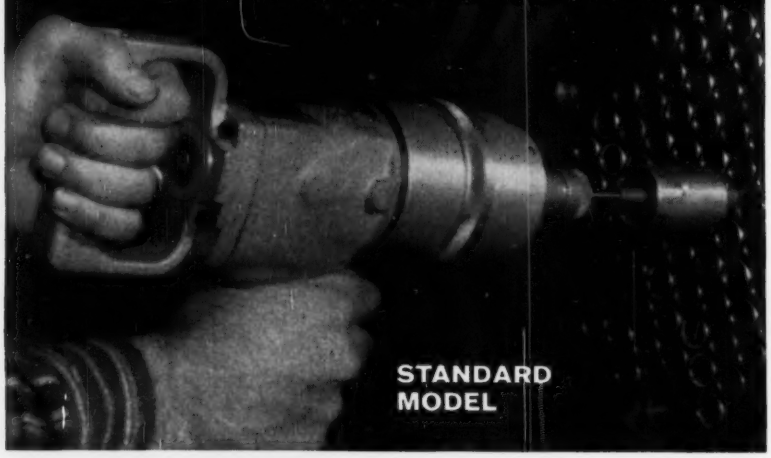
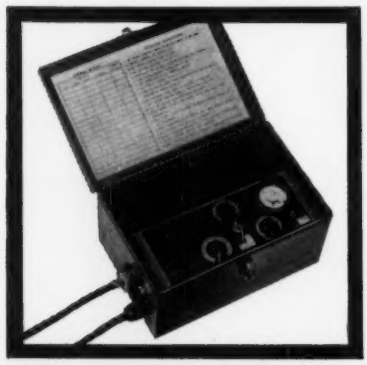
ELLIOTT air magnetic tube expander drives

automatically controlled for fast, accurate tube rolling



Designed for faster, precision tube rolling, the standard model Elliott Air-Magnetic drive is setting new records for speed and accuracy. Some operators average 12 tubes per minute. Desired torque easily preset by rotating forward end of unit. No tools needed. Rolling stops when preset torque levels are reached. Includes trigger-controlled, explosion-proof air motor in single unit. Magnetic control, no springs. Balanced for easy handling. For tubes ¼ in. through 3 in. *Standard model* handles most jobs. *Heavy-duty* for higher torque.

ALSO Electric Control ... Tube Expanders ... and Related Accessories



Elliott offers the Automatic Electric Control—an accurate torque-limiting device designed for tube expanding with any standard tapping motor. Also, a complete line of tube expanders, with rotating, parallel, self-feeding rolls. Available in 4 sizes, ranging from ¼ in. to 3½ in. O.D.

Other related accessories include Elliott tube gage, tube plugs, tube pilot, and tube rolling lubricant.

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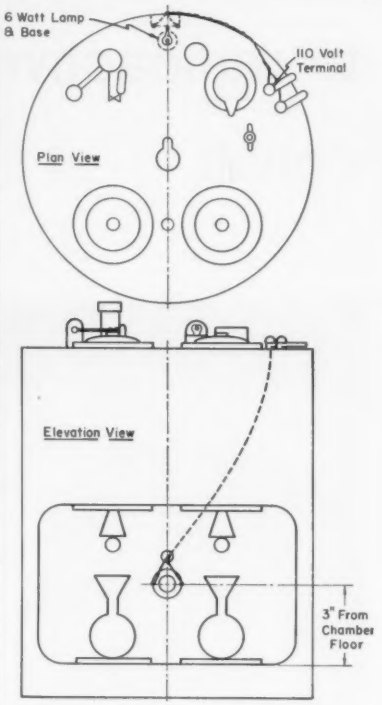
How To Do It . . .

bers by ASTM method D-88 because the oil coats the inside of the receiving flask and obscures the meniscus. By attaching a small light in the receiver compartment of the viscosimeter, sufficient illumination is obtained so that the viscosities of very



dark and thick oils can be determined with little difficulty.

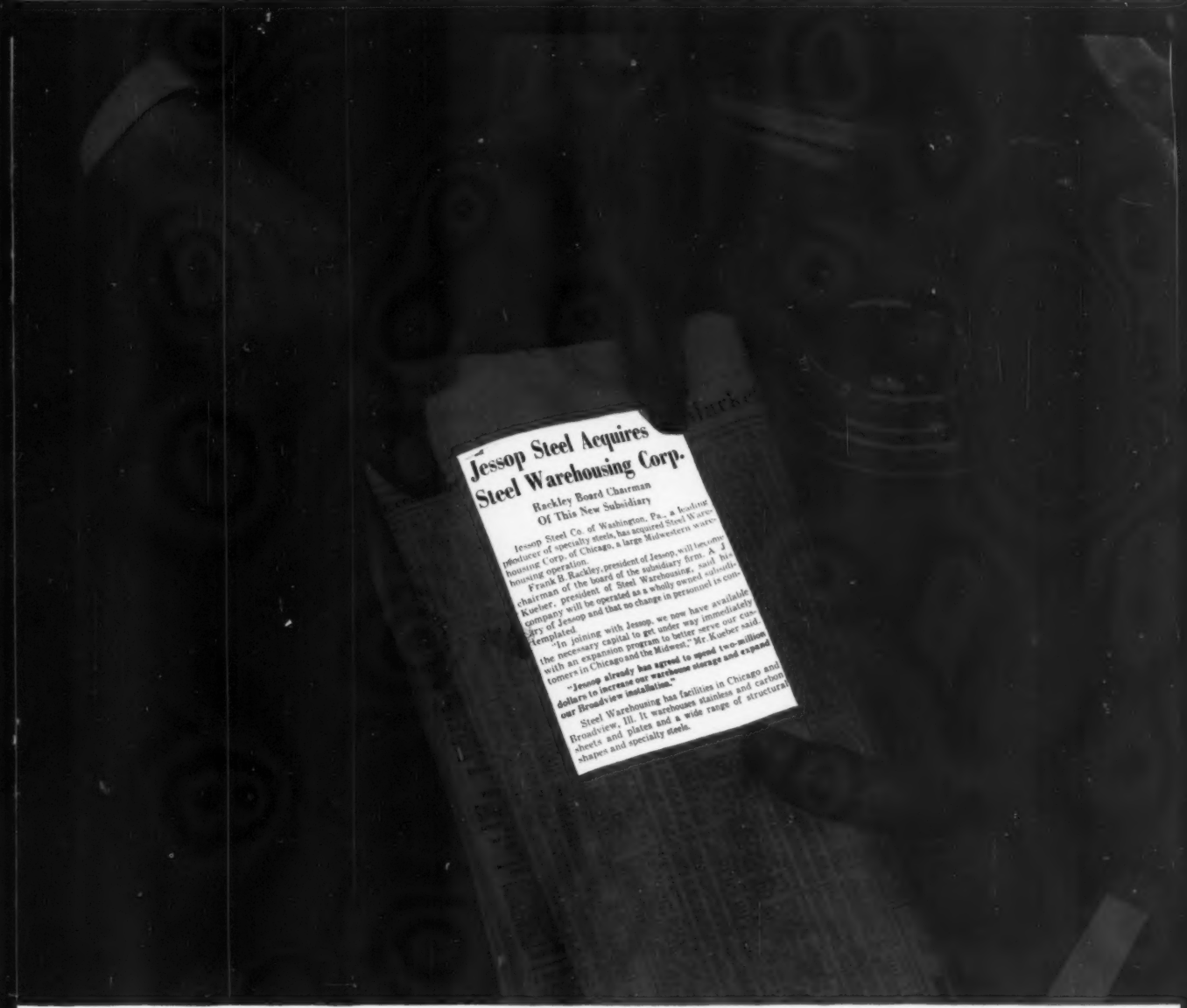
Two insulated leads may be run from the 110-volt plug terminals at the top of the instrument, down the outside of the machine, through a small access hole drilled in the back of the receiver chamber, and connected to a 6-watt lamp base bolted to the wall of the chamber as shown in the figure. The lamp burns continuously while the apparatus is in use.

This idea was submitted by John W. Toole, Northern Natural Gas Co., Kismet, Kansas.

Pressure Gage Needle Shuts Down Transfer Pump

When duplex pumps are used to transfer tank bottoms, or in other uses around the refinery where they may not be attended constantly, a shutoff switch may be easily rigged up with a pressure gage as shown. The gage is on the downstream side

For more data on advertised products, use Readers' Service Cards, last page.



Jessop buys Steel Warehousing Corporation . . . another reason for your confidence!

When you specify Jessop specialty steels, you've got good reasons for that decision. For example . . .

With Jessop, you're dealing with success. Although it's only two years since the acquisition of Green River Steel, Jessop now adds Steel Warehousing of Chicago. Already a two million dollar expansion of warehousing facilities is underway.

This fast growth didn't just happen. It results from the Jessop policy of producing the highest quality specialty steels *and keeping delivery promises!*

Yes, you have good reasons to be confident when you specify Jessop.

VMA 6721

JESSOP
STEEL COMPANY
Washington, Pennsylvania

Subsidiary Companies:

Green River Steel Corporation, Owensboro, Kentucky
Jessop Steel of Canada, Ltd., Wallaceburg, Ontario
Jessop Steel International Corporation, New York City
Steel Warehousing Corporation, Chicago and Broadview, Ill.

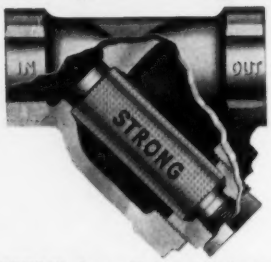
Stainless, alloy, tool, cast-to-shape, and forging steels, precision ground flat stock, and other specialty steels

cleaner steam systems... more positive regulation... use

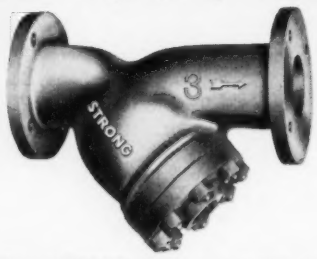
STRONG

STRAINERS

Built-in preventive maintenance • positive protection against dirt and scale in a system • clog-free operation • quick, simple cleaning



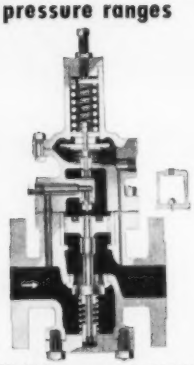
STRONG Strainers with threaded pipe connections: semi-steel (¼"-3"), cast steel (⅜"-2") and cast bronze (½"-2").



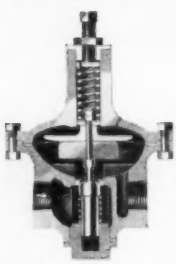
Flanged STRONG Strainers: semi-steel and cast steel (1½"-6"). Block Steel Strainers available for pressure to 10,000 psi.

REDUCING VALVES

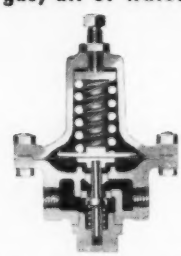
Accurate pressure control • simple adjustment • trouble-free operation • long service life • wide selection of types, sizes and pressure ranges • for use with steam, gas, air or water



Type "C" Valve: screwed (½"-1½") or flanged (2"-4") stainless steel trim, for 0-250 psi (semi-steel), 0-600 psi (cast steel).



Type "K" Valve: screwed (½"-1½"), built-in strainer, for pressures to 225 psi (semi-steel).



Type "O" Valve: screwed (⅜"-¾"), for pressures to 225 psi (semi-steel).

For complete information on these and other STRONG STEAM SPECIALTIES, contact your local STRONG Distributor or write for your copy of the new Catalog No. 69A today.

STRONG, CARLISLE & HAMMOND

508 Sandusky Street • Conneaut, Ohio

steam traps • air traps • float traps • F and T traps • vacuum or pumping traps • continuous blowdown valves • separators • engine stops

How To Do It . . .

of the pump and whenever it loses its suction, the pressure falls and shuts down the motive power. It can be connected to a solonoid switch, which will shutoff an electric motor, or to the low tension circuit in the ignition

system on an internal combustion engine.

The connection was simply made by drilling a hole in the glass of the pressure gage and installing a stove bolt so the gage hand will touch it at the proper time to shut off the power. The glass can be rotated slightly to adjust the shutdown pressure. On gas engines, this grounds the low tension circuit in the ignition system. When the pump is powered by an electric motor, the connection is made so current is passed through a solonoid which throws the main switch on the motor. This device can be also used to shutdown the engines where the pressure exceeds a predetermined limit.

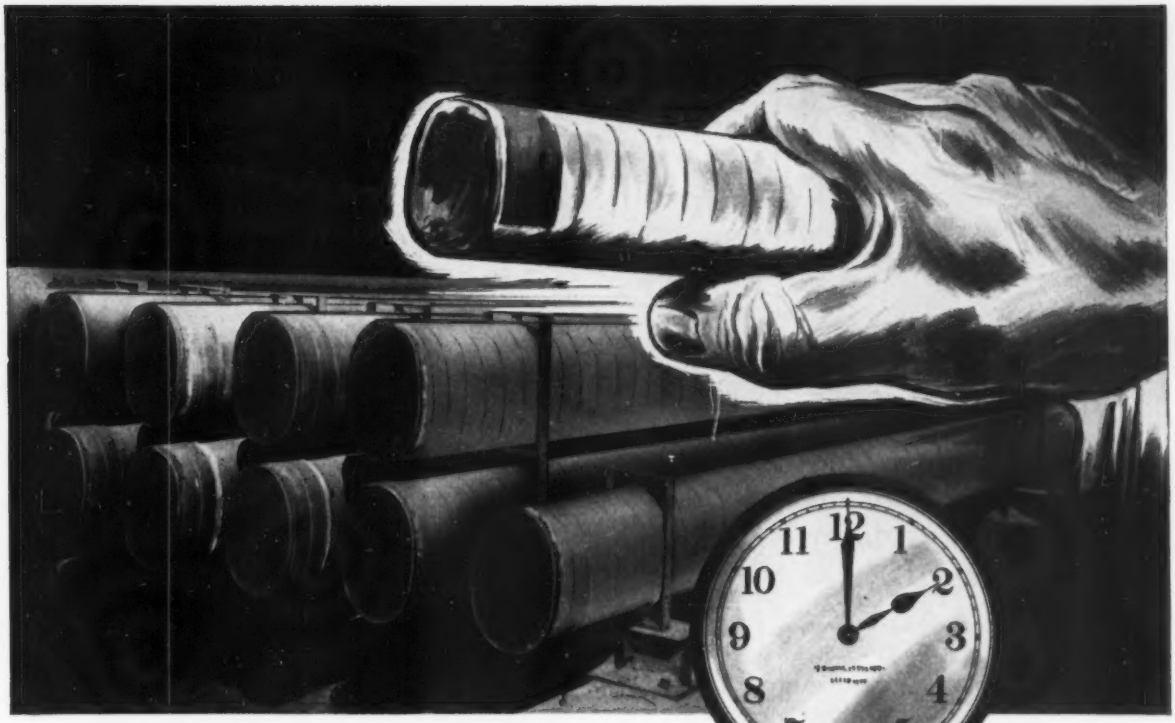
Bends in Pipe Made Easy With Pipe Jacks, Casters

Have your pipefitters suffered from "bends?" Every pipefitter at one time or another has had the problem of making a good pipe bend.

Here is an idea that will help him do the job better. All that is needed is a couple of pipe jacks with casters to use along with the pipe bending machine. By using the casters, the pipe jacks can roll with the ends of the pipe as it is bent. By keeping the pipe level, the jacks with casters prevent the rolling that could otherwise ruin a good pipe bend.

The casters are removable, so they can be stored by the pipe fabricators in their cabinet. These casters should be used only with the pipe bending machine. The pipe jacks, however,

For more data on advertised products, use Readers' Service Cards, last page.



IN JUST A FEW HOURS... *Sometimes Minutes*

Brown Heat Exchangers can be changed to meet any duty!

One key to profitable petroleum operation today is flexible equipment that can be rapidly adjusted to meet any desired capacity dictated by market conditions. Brown Fintube sectional units, unlike single-unit shell and tube exchangers, are easily and quickly added or subtracted to meet any desired capacity.

When cutbacks are necessary, you remove or valve off the required Brown sections. If capacity expands, you simply add or valve on enough sections to meet requirements. At a moment's notice with minimum maintenance, you are operating efficiently on any new or different capacity situation.

Because of this extreme usage flexibility, Brown high efficiency units are never obsolete, never in a scrap yard, or on the used equipment market. They are where they belong, *profitably* working for you.

HEAT EXCHANGE SURFACE
BROWN FINTUBE
HEAT TRANSFER PRODUCTS

BROWN FINTUBE CO.

302 HURON STREET • ELYRIA, OHIO
Telephone: FAirfax 3-3291

FREE HEAT EXCHANGER MANUAL!

Please send Bulletin 512 containing description, advantages, uses, specifications, details and selection data on modular Brown Units.

NAME_____

FIRM_____

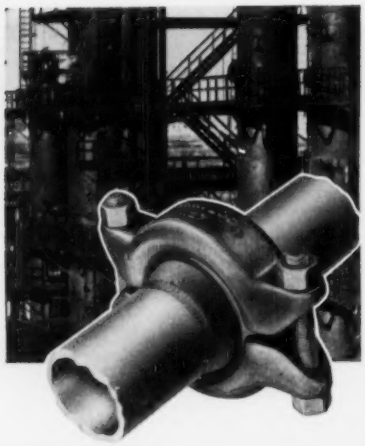
ADDRESS_____

CITY_____ ZONE_____ STATE_____

PR559

THERE'S *MORE* TO HEAT EXCHANGERS THAN INITIAL PRICE!

For more data on advertised products, use Readers' Service Cards, last page.



GRAYLOC Connections Hold High Pressures With No Leaks During 197,000 Loading Cycles

GRAYLOC connections in use at a Texas chemical plant* were cyclically loaded with pressures from 2,500 to 9,000 psi 197,000 times without a leak. Although these connections are rated at 12,000 psi, two of them were tested at maximum static pressure to learn whether fatigue action had changed the ultimate capacity. Both held at pressures far exceeding rating and one held without leakage to 27,000 psi.

When high pressures are your problem, specify GRAYLOC connections for safety, low initial cost, low maintenance cost. Write for the whole technical GRAYLOC Test Data story today.

*Taken from a letter in our files

GRAY Tool Company

5901

P. O. BOX 2291 HOUSTON, TEXAS
REpublic 4-1641

MAIL THIS COUPON TODAY

GRAY TOOL COMPANY
P. O. Box 2291 Houston, Texas

Please send me the GRAYLOC Test Data.

Name_____

Company_____

Title_____

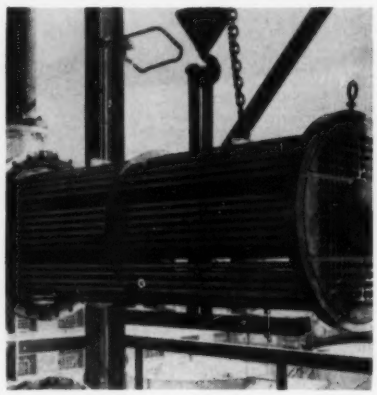
Address_____

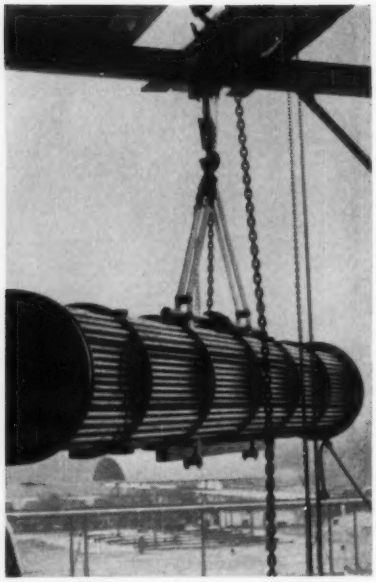
City_____ State_____

How To Do It . . .

can be used in other ways without the casters.

This idea was submitted by Dan Proffitt and W. R. Brennan, Ethyl Corp., Pasadena, Texas.





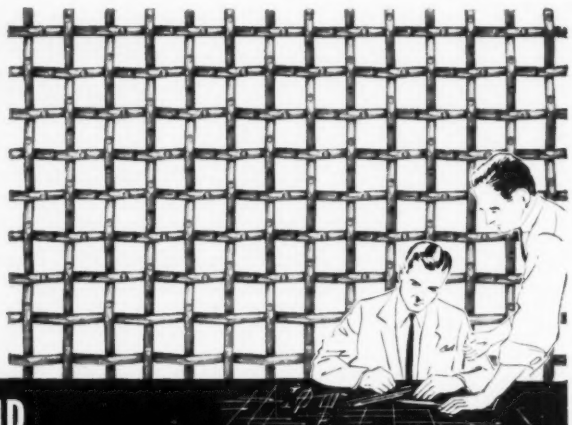
Make These Handy Tube-Bundle Supports

Handling heat exchanger bundles before and after they have been cleaned is a problem, particularly if they are in elevated structures.

One of PETROLEUM REFINER's Italian readers developed two methods for supporting tube bundles. Look them over. They may be adaptable to your plant.

The supports were developed by Vittorio Amato, I.C.I.P., Mantova, Italy.

Filtration
Straining
Screening
Catalysts



CLEVELAND
Has the Answer to All Wire Cloth Problems

Whether your problem is bulk or fabricated parts, filtering, straining, screening or catalyst, get in touch with Cleveland. Over 40 years experience in the weaving and fabrication of industrial wire cloth provides the answers to your screen problems.

Immediate shipment of many standard meshes or weaves from stock. Fabrication into products is our engineering specialty.

SEE OUR AD IN REFINERY CATALOG

Send your specifications or call today. We'll be glad to consult with you on your wire cloth problems without delay. Ask for Bulletin No. 10.

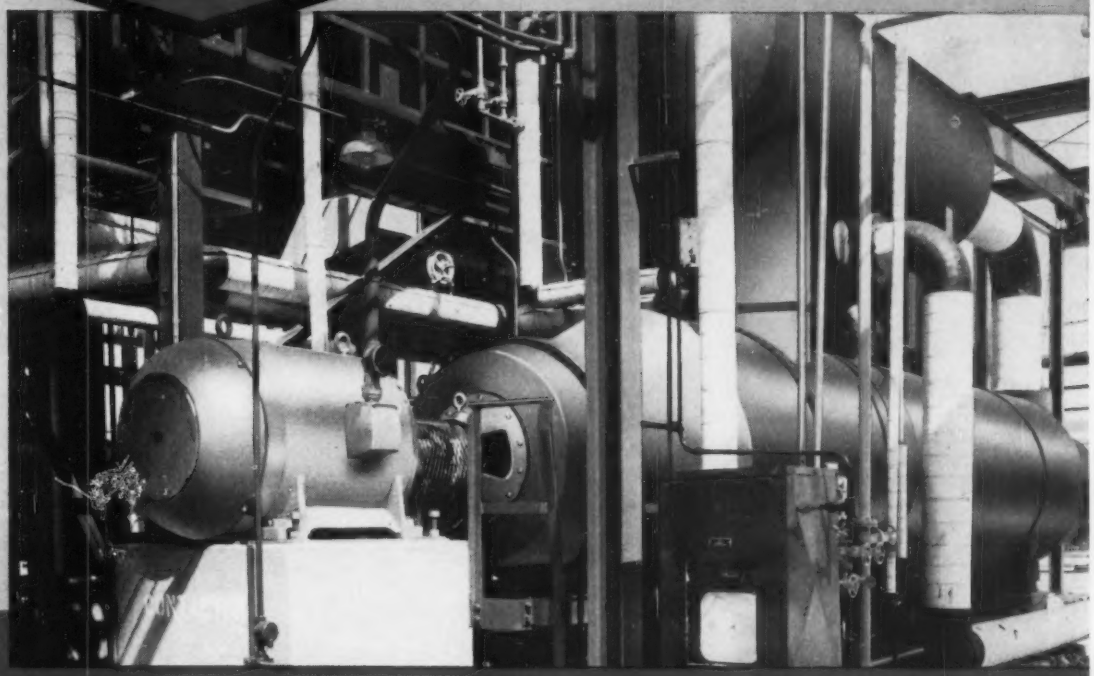
THE CLEVELAND WIRE CLOTH & MFG. CO.
3671 EAST 78th STREET, CLEVELAND 6, OHIO • DI 1-1832

For Highest Octanes...

REFINERS CHOOSE

STRATCO
Reg. U. S. Pat. Off.

Effluent Refrigerated ALKYLATION



With the Lowest Acid Consumption Record in the Industry

Recently built Stratco units have established the lowest acid consumption records in the industry. Another characteristic of these new plants is a significant reduction, or in many instances complete elimination, of fractionating column reboiler fouling.

Highest quality alkylate and easiest mechanical operation of Stratco installations are other advantages.

Electronically computed flow diagrams and material balances incorporating these improvements are available quickly and without cost.

Representatives

D. D. Foster Co., Pittsburgh
D. D. Foster Co., S. Charleston, W. Va.
Lester Oberholtz, Los Angeles
Rawson-Houlihan Co., Inc., Houston
The Rawson Co., Inc., Baton Rouge
F. J. McConnell Co., New York

Stratco Effluent Refrigeration licensed by Stratford Engineering Corporation. We cooperate with your contractor in plant design.

STRATFORD ENGINEERING Corporation

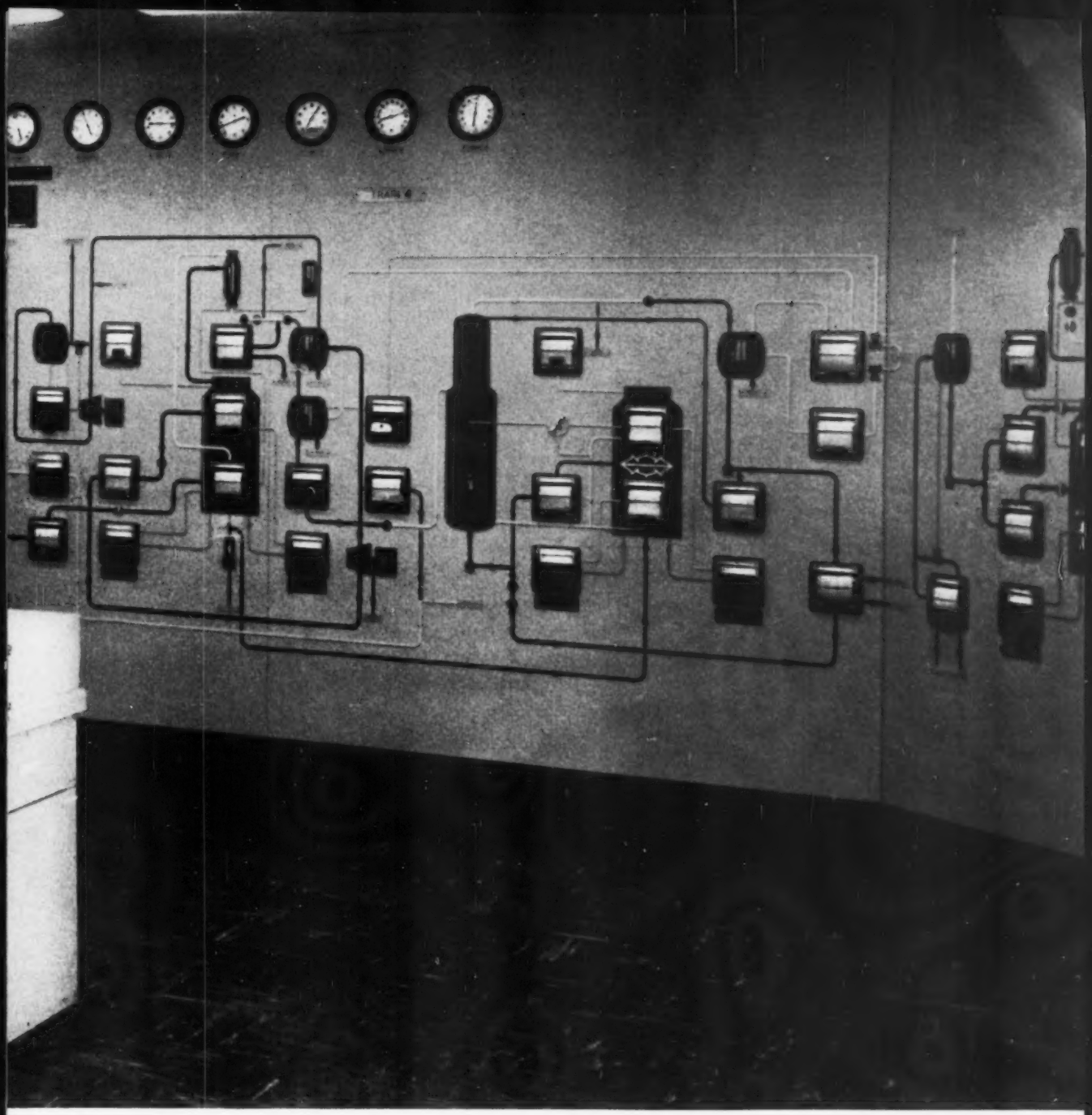
612 West 47th St. — PETROLEUM REFINING ENGINEERS — Kansas City 12, Mo.

"readability and flexibility—that's why we specified

reports S. Edward Roth,
Chief Instrument Engineer,
Tidewater Oil Company
Delaware Refinery

It's the full-scale, vertical, 4-inch strip chart that makes a pneumatic Consotrol instrument so easy to read—even from a distance. 33% larger than most small-case instrument charts. An important difference in large control centers where operators "sweep" as many as 100 instruments at a time.

As for "flexibility", Foxboro Consotrol instruments stand out in two ways. One—because of the Model 58 Controller's 500% proportional band—the widest proportional band of any small case controller—and its reset and derivative units, which easily plug-in with *no* re-calibration necessary. Operators find these fea-



pneumatic Consotrols* for our new Tidewater Refinery"

tures especially helpful when "tuning" controllers to a new process.

And second—at the Tidewater Control Center shown here, there are 1, 2, and even 3-pen recorders; 1 and 2-pointer indicators; as well as recorders and indicators with integrally-mounted Model 58 Consotrol Controllers.

"Readability and flexibility"—plus day-in, day-out dependability of control. You get them all with Foxboro Consotrol instruments. Write for Bulletin 13-18—it has all the details. **The Foxboro Company, 745 Neponset Avenue, Foxboro, Massachusetts.**

*Reg. U. S. Pat. Off.

SHOWN ABOVE: Graphic control panel for catalytic desulfurizer unit. Tidewater Delaware Refinery. Over 400 Foxboro Consotrol Instruments are used in this ultramodern refinery.

FOXBORO

REG. U.S. PAT. OFF.

CONSOTROL INSTRUMENTATION

SAFETY IN THE RIGHT PERSPECTIVE

with Flexitallic Spiral-Wound Gaskets

In this enlarged sectional view, you can see the Spiral-Wound Gasket construction originated by Flexitallic in 1912. And you can see Flexitallic Blue, the blue dye in the Canadian asbestos filler, which is the mark of an engineered Flexitallic Gasket.

Flexitallic means sealing at its safest. You get performance you can depend on throughout all pressure/temperature ratings, because the compression characteristics of the gasket are always related to the pressure/temperature ratings of the flanges with which they are assembled.

When fluids are confined in a critical pressure/temperature range . . . when flanged joints are subject to thermal and mechanical shock; vibration, weaving, and other joint stresses . . . engineers demand the maximum in gasket performance.

That's why they specify Flexitallic Spiral-Wound Gaskets.

FLEXITALLIC GASKET CO.
8th & Bailey Sts. Camden 2, N.J.

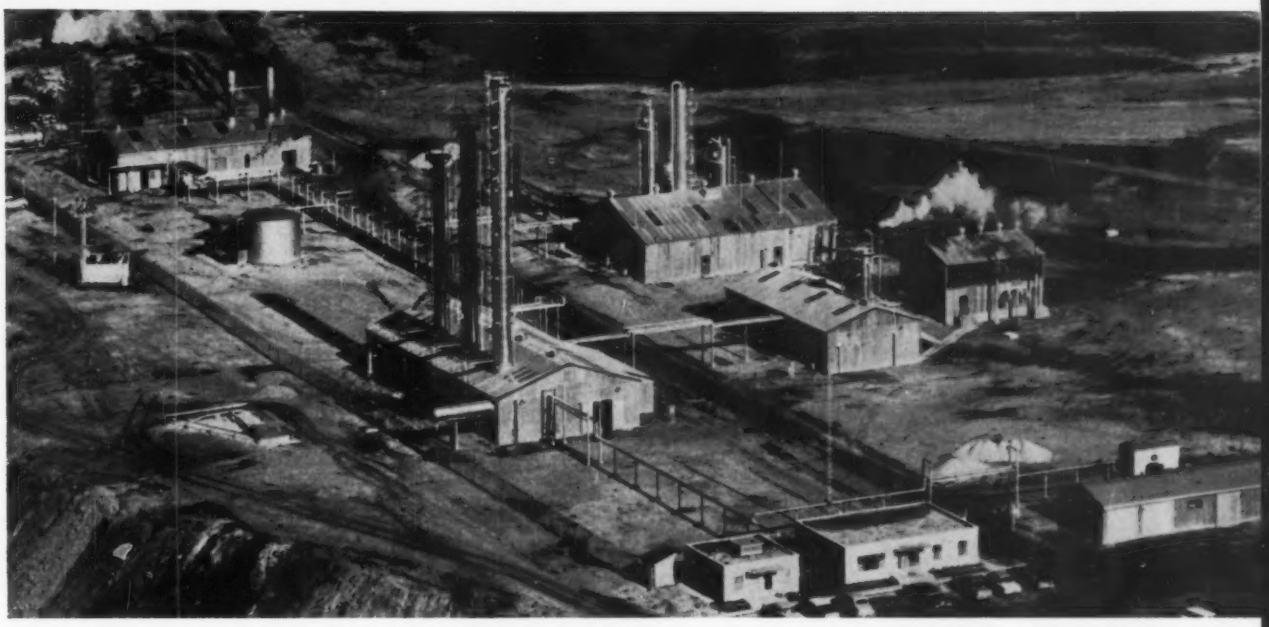
Flexitallic®
SPIRAL-WOUND GASKETS

FOR PIPE FLANGES, PRESSURE VESSELS AND PROCESS EQUIPMENT

*Flexitallic is a registered tradename. No one else can make a Flexitallic Gasket. Look for *Flexitallic Blue* — it's our exclusive blue-dyed Canadian asbestos filler.

For more data on advertised products, use Readers' Service Cards, last page.

Who's Building...



Completion is slated for this Fall on 20-MMcf expansion of Alberta gas plant.

British American Expands Nevis Plant

Compression and refrigeration are combined to remove liquid from the raw gas

British American Oil Co., Ltd. will spend $1.5 million dollars to expand capacity of its Nevis, Alba., gas conservation plant from 15 to 35-MMcf of raw gas daily.

The plant will process the B-A and Imperial Oil Co. share of production from the nearby Nevis wet gas field, for delivery to the Alberta gas trunk line for Trans Canada Pipe Line.

The expansion will include inlet facilities, amine gas treater, amine liquid treater, refrigeration units, liquid treating and fractionation units, sulfur recovery and boiler plants.

Contracts have been awarded to Poole-Pritchard for construction of sulfur and boiler facilities, and to Brown & Root for hydrocarbon facilities. Completion is slated for this fall.

The plant, 25 miles east of Red Deer, has been operating since December, 1956. Work started in 1954 when B-A engineers began studies to see if solution gas from Alberta's Fenn-Big Valley and Stettler oil fields could be economically processed. Until then, gas production in the area was insufficient for processing and solution gas was flared in the field.

The process for stripping propane, butane, and natural gasoline from the raw gas involves (1) extraction of raw liquid hydrocarbons and, (2) separation of this liquid into propane, butane and liquid gasoline.

Raw gas, in solution in the oil until the latter reaches the surface at production time, is removed at wellhead separators in the Stettler and Fenn-Big Valley fields. Solution gas is then transported by low-pressure pipe line from the separators to a compression-refrigeration plant in each of the fields. These have 10 and 3 MMcf capacities, respectively.

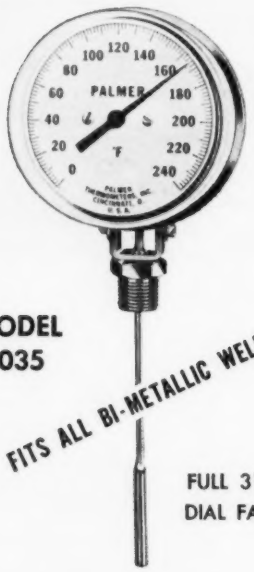
There, compression and refrigeration removes a mixture of raw liquid hydrocarbons. Remaining residue gas is "sweetened" by sulfur removal and delivered to Canadian Western Natural Gas Co. for distribution.

The liquid hydrocarbon mixture is carried by high-pressure pipe lines to the fractionation plant at Nevis, where propane, butane and natural gasoline are removed. Liquid products are either stored at the plant or carried by

Outstanding Accuracy

PALMER

Dial Thermometer



Check these functional features

- Direct-drive Bourdon Coil with a filled system for longer lasting accuracy.
- Stem can be placed at any desired angle and case can be rotated to most readable position.
- External calibration for zero setting.
- Unaffected by stem alignment.
- Accurate to one scale division.
- No sticking at any temperature.
- Non-corrosive case.

PALMER

THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2515 Norwood Ave., Cincinnati 12, O.

Building . . .

product lines to nearby rail and truck loading racks.

Three propane storage tanks at Nevis each hold 49,000 gallons. Two butane tanks each have a capacity of 47,000 gallons, and two natural gasoline tanks each hold 24,000 gallons.

One of the largest processing vessels ever constructed in the Southwest was designed by Delta Engineering Corp., Houston, and fabricated by General Welding Works, Houston. The 122-foot demethanizer column, which weighs 355,000 pounds, is part of a $3-million project at Arkansas Louisiana Chemical Corp.'s Hamilton plant, Magnolia, Ark.

Shell Oil Co. has begun construction of a gas processing plant in Texas' lower Rio Grande Valley. Planned to eventually produce 15-MMcf per day of residual gas, the plant will have a low-temperature gas processing unit with product stabilization to recover liquid hydrocarbons from casinghead and gas-well gas. Raw gas will come from Arkansas City, North Rincon and Javelina fields.

Mobil International Oil Co. has awarded the engineering contract for a 65,000-bpd refinery at Mersin, Turkey to Foster Wheeler Corp. Mobil International is agent for Anadolu M. Tasfiyehanesi, A. S. (ATAS), a Turkish company that will operate the refinery. ATAS is jointly owned by British Petroleum Co. Ltd., California Texas Oil Corp., Mobil International and Shell Petroleum Co., Ltd.

The $50-million refinery, being built by Turkish government request, is scheduled to go on stream in late 1961. Site investigation work at Mersin is underway, with construction to begin in about six months.

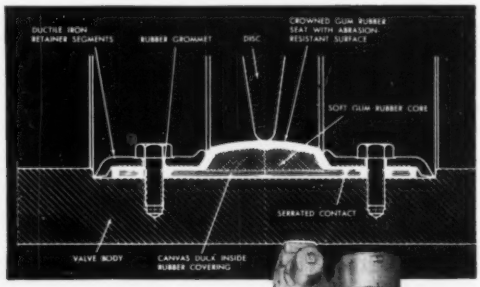
Initial installations will include crude distillation, catalytic reforming and kerosine desulfurization units. They will process Middle East crude, and produce automotive gasoline, kerosine, diesel fuel and heavy fuel oil.

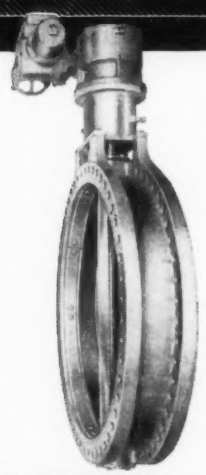
The refinery will also have two berths to handle simultaneously two tankers of up to 50,000 tons each. A smaller pier will handle 20,000 ton vessels, and a barge wharf will be built.

Terms of the agreement with the Turkish government provide that the refinery may process imported crude oil until production of Turkish crude of suitable quality becomes available.

Fertilizantes Sinteticos, S. A., has completed at Callao, Peru, its first synthetic ammonia plant. Designed and built by Montecatini Co. of Italy and employing a Fauser-Montecatini process,

DRIP-TIGHT SHUT-OFF *with* ROCKWELL *BUTTERFLY VALVES*





The matchless new "Wedge-Lock" rubber seating provides drip-tight shut-off in Rockwell Butterfly Valves. Its unique construction makes leak-proof closure sure and safe. Valves can be made with full rubber lining.

Other advantages—minimum restriction to flow, positive manual or automatic control, easier installation in less space, minimum maintenance.

Made in all sizes, in 25-, 50- and 125-lb service in all industrial applications.

Write for Bulletin 582.

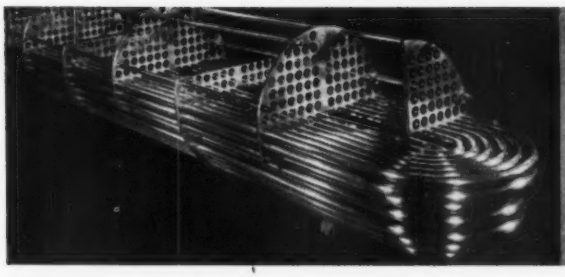
ROCKWELL SINCE 1888 BUILT

W. S. ROCKWELL COMPANY

Valves - Butterfly · Slide · Diaphragm · Special

2369 ELIOT STREET • FAIRFIELD, CONN.

For more data on advertised products, use Readers' Service Cards, last page.



CONDENSER AND HEAT EXCHANGER CLINIC

Edited by David S. Hibbard, Metallurgical Engineer
The American Brass Company, Buffalo 5, New York

New tube mill equipment gives designer of heat-transfer units freer hand in meeting new trends

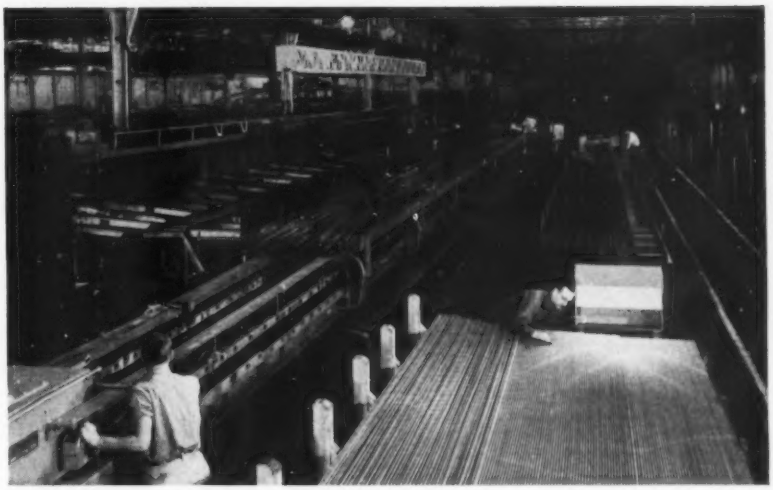
With the installation of new production and testing equipment, The American Brass Company now offers the most complete service available to users of condenser and heat exchanger tubes.

Long lengths. To gain advantages in construction, processing, or installation, designers can lengthen equipment considerably. Tubes can now be drawn up to 100 feet. Most of the longer tubes are required as U-bends, but in some instances may be shipped as straight lengths.

U-bends. Tubes from $\frac{3}{8}$" O.D. to $1\frac{1}{2}$" O.D. with wall thicknesses from .049" (18BWG) to .134" (10BWG) can be bent on a radius of from $1\frac{1}{4}$ times the tube O.D. to 30".

Dual Gage. Where high temperatures and pressures are involved, it may be desirable to thicken the tube wall in the area of short-radius bends on U-bend tubes. Walls are thickened one Stubs' Gage No. to compensate for thinning of metal in the bending.

Thickened Tube Ends. To compensate for thinning by rolling or by impingement corrosion caused by high velocities, tubes may be supplied with the wall thickened at one end one or more Stubs' Gage Nos. The extra thickness may be on the outside or inside of the tube as required.



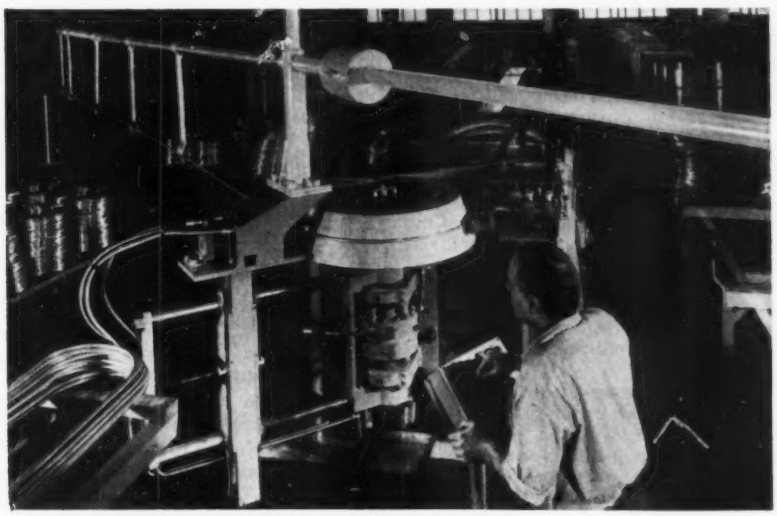
GENERAL VIEW of new American Brass Company equipment which can draw copper and copper alloy tubes in lengths up to 100 feet.

Relieving Stresses. All U-bend tubes, other than copper, are annealed at the bend area after bending, to eliminate the hazard of stress-corrosion cracking which might occur in service due to stresses that may exist as a result of the bending.

Testing. U-bends are tested hydrostatically at ASTM Specification pressures —or at ASME Code pressures up to 6000 psi on request, if the tube size will stand it. Electronic inspection with eddy-current equipment is available also, when required.

Shipping. U-bend tubes are shipped packed for ease in handling and storage.

Technical Assistance. For more detailed information on extra-long tubes, U-bend, Dual-gage, or Duplex tubes to meet special problems, address: The American Brass Company, Buffalo Division, Buffalo 5, New York. In Canada: Anaconda American Brass Limited, New Toronto, Ont. 5957 Rev



BENDER CAN produce U-bend tubes with straight leg up to 50' long.

ANACONDA®

TUBES AND PLATES FOR CONDENSERS AND HEAT EXCHANGERS

Made by
The American Brass Company

For more data on advertised products, use Readers' Service Cards, last page.

The V.P.
said,

"STOP

. . . Stop right now, if you're trying to tell me there's anything different about your cobalt moly catalyst."

That's the kind of talk we like.

Sure, we believe in recommending our own product . . . for desulfurization, denitrogenation, hydrogenation of olefins, in the hydrotreating of naphtha feeds to reforming processes, and other general hydrotreating service. But we not only recommend it, we can give you some unique assistance in making sure you're getting all the return you can.

As process designers, our people know your problems and can fully understand your special requirements. From actual experience in industry, they know the importance of details so often forgotten, such as handling costs, storage problems, and special information for your processing personnel.

Catalysis is a way of life with us. Tell us your requirements, and let us prove it to your advantage.

*

HOUDRY

CATALYSTS

HOUDRY PROCESS CORPORATION

1528 Walnut Street, Philadelphia 2, Pa.

*Houdry means Progress . . . through Catalysis

Building . . .

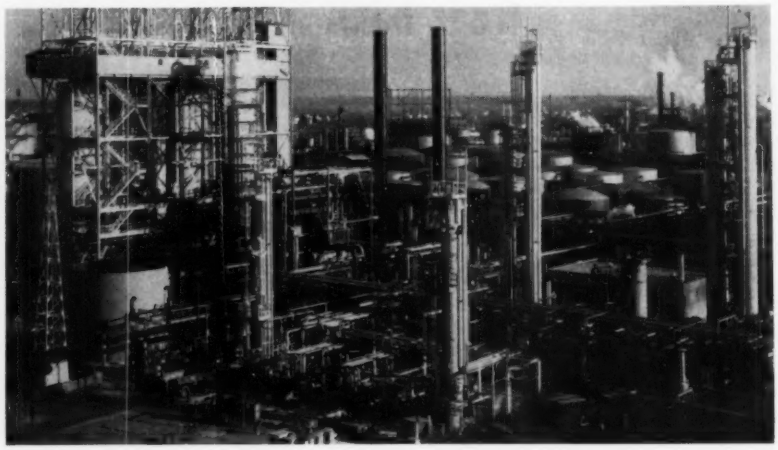
the plant will produce, based on a 330 day year:

- 20,000 metric tons anhydrous ammonia
- 54,000 metric tons nitric acid, 53% by weight
- 35,000 metric tons ammonium nitrate—fertilizer and technical grades
- 7,500 metric tons ammonium sulfate—fertilizer grade
- 1,500 metric tons nitric acid, 98% by weight

The $10 million Callao plant is the first in South America to make hydrogen by the partial combustion of fuel oil, to be supplied by Northern Peru. Capacity of the partial combustion plant is 16,500 metric tons per year.

The fertilizer-grade ammonium nitrate plant uses a granulating device based on revolving disks, giving a prilled product suitable for direct distribution on the ground.

Located on the ocean the plant will use sea water at 630,000 gallons per hour to cool condensers of the plant's thermo-electric power station.



Mobil Completes Paulsboro Coking Plant

A new 19,000-bpd delayed coking unit —designed, engineered and constructed by The Lummus Co. for Mobil Oil Co.'s Paulsboro, N. J., refinery—is on its initial run. The coker has four coke drums 19 feet in diameter by 63 feet tangent to tangent, and is designed for 764 tons per day of coke, making it "the largest initial capacity coker ever built in the U. S.," according to the company.

Feedstock is a mixture of seven various reduced crudes or blends of residua whose gravity varies from 3 to 14° A.P.I. Included are furfural extract, duosol tar and propane deasphalting tar.

The unit cokes heavy residual stocks, from other refinery units, which previously were blended into fuel oil. It makes fuel gas, butane-butylenes, light and heavy gasolines, light and heavy gas oils, and coke. The coker includes a gas recovery section, sulfuric acid treater for gasoline, amine treater for light hydrocarbons, and a caustic treater for the butane-butylene stream.

Skelly Oil Co.'s new alkylation unit at El Dorado, Kan., is complete and producing at full capacity. The 3,500-bpd high-octane gasoline plant was engineered and constructed by Skelly. The El Dorado refinery has a 42,000-bpd capacity.

U. S. Industrial Chemicals Co., which recently started up its 75-million-pound-per-year polyethylene plant at Houston, is already planning to double capacity of the plant. Scheduled for 1960 completion, the expansion will up present capacity to 150 million pounds per year.

California Spray-Chemical Corp. plans to build two major processing units at its Kennewick, Wash., multi-million dollar fertilizer plant. Nitric acid and ammonium nitrate plants will be built by Chemical Industrial Corp., Cincinnati, at a cost of $2 million.

Imperial Chemical Industries, Inc., will build what it says is Britain's first big acrylonitrile plant at Teesside, Northern England. Production is to begin late in 1959, with chief output to be acryllic fibers.

Gulf Oil Corp.'s new $10-million benzene plant at Port Arthur should be on stream by midyear. Originally scheduled for completion by mid-1958, the plant will have a 30-million-gallon-per-year benzene capacity, and will also produce toluene.

Pan American Petroleum Corp. has completed its processing plant and started gas-processing operations at Beaver Creek, near Riverton, Wyo. The plant was constructed by O. L. Olson Construction Co., Houston, and began full-scale operations April 1. Initial de-

For more data on advertised products, use Readers' Service Cards, last page.

HYDROFINING REPLACES ACID TREATMENT

To eliminate pollution of air and effluent water, reduce operating costs, and to produce a sulphur free finished product, a large Gulf Coast refiner recently placed in operation the above pictured 6000 barrel per day HYDROFINING Unit designed to supplant acid treatment in processing close boiling range naphthas.

Feed stock is vaporized and mixed with hydrogen which catalytically reacts with sulphur contained in the feed stock mostly in the form of mercaptans, to form hydrogen sulphide which is further processed to recover elemental sulphur. After HYDROFINING the liquid product is washed with caustic and filtered through charcoal.

HUDSON furnished mechanical design, materials and equipment; and constructed the HYDROFINING Unit and the Fractionating Unit shown at the left of the picture.

The services of the HUDSON organization, with over 25 years experience in process design, mechanical design and construction are available to process industries in any part of the free world.

DESIGNERS AND CONSTRUCTORS OF PROCESS PLANTS FOR THE OIL, GAS, CHEMICAL, AND MINERAL INDUSTRIES

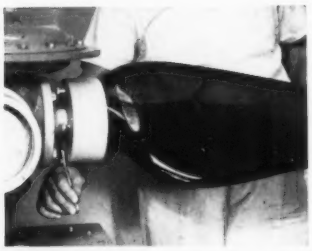
HUDSON

ENGINEERING CORPORATION

FAIRVIEW STATION • HOUSTON, TEXAS

OFFICES: 9935 Santa Monica Blvd. Beverly Hills, California • 122 East 42nd St. New York 17, N. Y. • 199 Bay Street Toronto, Ontario, Canada • 17 Stratton St., Picadilly London W. 1, England • Corrientes 1115 Buenos Aires, Argen. • Rua Mexico 45 Rio de Janeiro, Brazil

Lightweight.



Easy installation and adjustment.

NEW HUDSON TUF-LITE FANS

After six years of development work and tests of trial field installations operating under wide ranges of conditions in cooling towers, finned tube coolers, and in highly corrosive chemical plant ventilating service, Hudson presents a new product—the TUF-LITE fan. The blades, cast in one seamless piece of fiber glass reinforced synthetic resin, are hollow, light and tough. TUF-LITE fans afford the following advantages over any other available type of fan:

SAFE: TUF-LITE blades being lightweight (about ¼ the weight of other blades with comparable capacity) and infrangible, eliminate the hazards to personnel and equipment existent through accidental throwing or disintegration of heavy metal, wood, or laminated blades while in service.

EFFICIENT: More air is moved at less horsepower because weight and finishing operations do not impose limitations on selections of best aerodynamic design; therefore nearly ideal airfoil cross sections, commercially attainable only in TUF-LITE blades, can be used. Blades will not sag or distort, and surfaces remain permanently smooth.

LOW MAINTENANCE: TUF-LITE blades are unaffected by corrosive, abrasive or impingement effects of hot saturated air, sand, rain, or hail, and have superior deterioration resistance to practically all corrosive vapors or liquids. Blade materials contain color pigment; no painting is necessary. Light weight reduces stress and maintenance on bearings, gears, drive shafts, and supports.

QUIET: The permanently smooth surfaces, very light weight, sustained perfect balance, and advanced aerodynamic design minimize noise.

EASE IN INSTALLATION: Light weight of blades and ingenious design of hub and blade coupling allows attachment of blades by one man using only small wrench. Coupling design assures uniformity of pitch of all blades, and as blades of same size are identical and interchangeable, perfect fan balance is preassured.

In replacement of present fans or in installations on new cooling equipment of any manufacture TAKE ADVANTAGE OF THE OUTSTANDING SUPERIORITY OF HUDSON TUF-LITE FANS.

Bulletin on TUF-LITE FANS
Available upon Request

TUF-LITE protected by U.S. copyrights, patents and patents pending

HUDSON
ENGINEERING CORPORATION

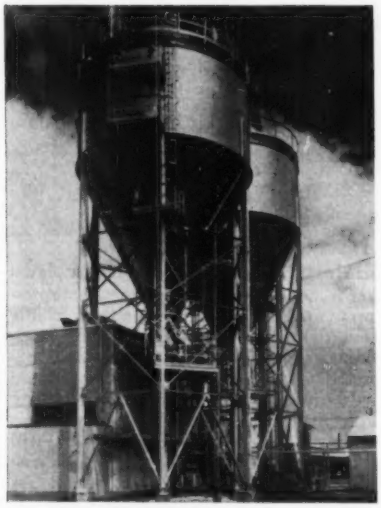
FAIRVIEW STATION • HOUSTON, TEXAS

sign capacity for optimum efficiency is 47 MMcf of gas daily, but is capable of handling 62 MMcf. Of this, 2.7 MMcf is casinghead gas.

The plant recovers propane, butane and natural gasoline. Total product recovery at design throughput rate is 38,500 gallons a day, including 13,500 gallons of propane, 13,000 gallons of butane and 12,000 gallons of natural gasoline.

Pan American operates the plant and the Beaver Creek unit for itself, Kerr-McGee Oil Industries, Inc., and Phillips Petroleum Co. Pan American owns about 85 per cent interest in the participating area covering the gas zones in the field and in the plant. In the oil zones, Pan American holds a 100 per cent interest.

Gas being processed is from all six productive formations in the Beaver Creek Field, three of which are gas zones. These are the Frontier, Muddy and Lakota. Both oil and gas are produced from the Mesaverde, Tensleep and Madison.



Goodrich-Gulf Chemicals, Inc.'s Port Neches, Texas, plant has completed facilities for volume production of synthetic cold rubber. Representing a $1.25 million investment, the new equipment will produce 15 million pounds of black masterbatch per month on a continuous-flow basis. Half of styrene-butadiene copolymer reactor lines, with their recovery and drying equipment, at the Port Neches plant has been converted to this production.

A feature of the Port Neches installation is the handling equipment for the large amount of carbon black required. Delivered to the plant in railroad cars, this powdery material is discharged into a unique zipper belt conveyor manufactured by B. F. Goodrich Co. This belt is automatically closed into a tube by rubber zippers as it leaves the unloading zone. Traveling in a covered trench, the belt moves to storage silos where the zippers open and the carbon black is discharged. The belt is more than 500-feet long and is rated as one of the largest installations of its kind in the world.

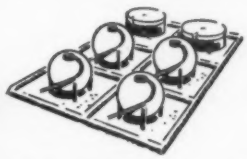
Morningstar-Paisley, Inc., has begun production of polyvinyl acetate emulsions at its new plant in Clifton, N. J. The company has also increased its Chicago-plant output of emulsions by 50 percent, doubling total Morningstar production of the materials. The Clifton plant also includes a facility for manufacturing liquid vinyl chloride and natural synthetic latex compounds.

Building . . .

The Texas Co. has placed on stream at Port Arthur, Texas, what it says is the first industrial process ever to be controlled by an electronic brain. A digital computer took over control of the processing on a $4-million refining unit, closing the so-called "loop" of computer control on a full-scale plant operation.

While carrying out its control program—gathering information from 110 sources and controlling 16 different streams, pressures, and temperatures in nearly every combination—the computer also checks the accuracy of its information, watches its own performances,

NOW!



Wipe out Weeds and Brush

for as long as **8** *to* **18** *months*

with one application of UROX®

Now you can wipe out troublesome weeds and brush faster, easier, at lower cost and for a longer time with just one application of Allied Chemical's UROX Weed Killer.

This powerful herbicide effectively handles weed killing jobs on tank farms, around refineries and pumping stations, and along pipelines. It destroys weeds and brush in non-crop areas wherever they form a fire hazard, an eyesore or a maintenance problem.

Longer lasting! Saves time and money! UROX tends to build up increasing soil sterility. Its herbicidal action can thus be extended from one year to the next with light booster doses. As smaller and smaller amounts are used over a period of time, you realize substantial savings.

Get the whole story! Send today for our new full-color UROX folder, "Candidly Speaking." You'll see unretouched candid camera evidence of UROX's effectiveness in many widely-separated geographical areas, many different climatic conditions. These actual photos from the field tell the UROX story with greater accuracy than words can convey.

To obtain your free copy of the new UROX folder, "Candidly Speaking," mail the coupon.

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

Weed Killer Dept. PR-59
GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL CORPORATION
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Please send free copy of the new UROX folder, "Candidly Speaking."

Name _____
Title _____
Company _____
Address _____
City _____ Zone _____ State _____

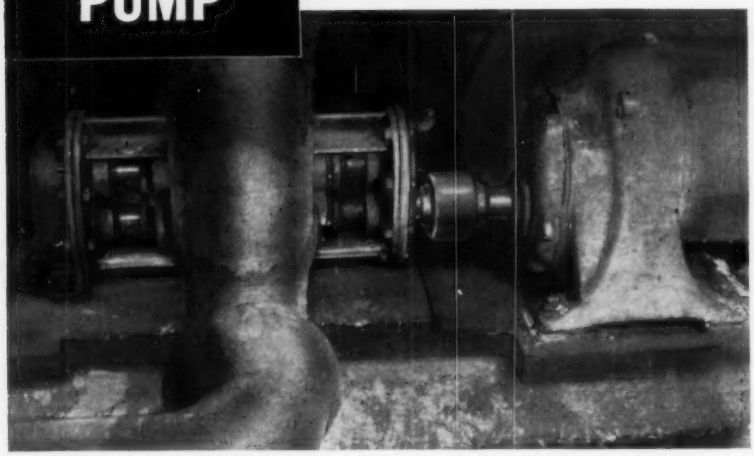
For more data on advertised products, use Readers' Service Cards, last page.

Johns-Manville Products Corporation

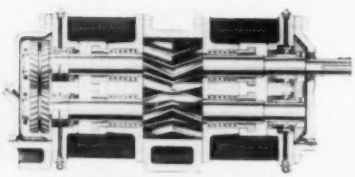
Pumps 230 gpm. of Asphalt at 460°F.

with Sier-Bath GEAREX® PUMP

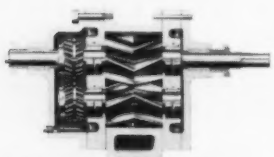
• This Sier-Bath Gearex Rotary Pump, external gear and bearing type, has been providing rugged service since 1956 at the Johns-Manville Building Products Division Plant, Fort Worth, Texas. Operating on 24 hour schedules, 5 days a week—often 7 days a week—the Gearex Pump handles 230 gpm. of Asphalt at 460°F. with viscosity from 160 to 7,000 SSU, at pressures from 60 to 100 psig. The pulseless discharge of the rotary design has proved especially valuable at this installation. All gears and bearings are externally mounted, never in contact with the hot asphalt.



***Sier-Bath* "Gearex" Pumps**



EXTERNAL GEAR & BEARING TYPE
for non-lubricating liquids



INTERNAL GEAR & BEARING TYPE
for lubricating liquids

Sier-Bath "Gearex" Pumps provide positive displacement, pulseless flow . . . quiet, vibrationless operation. Direct-connected up to 1800 RPM, they require no reduction gears. For high volumetric efficiency and long life there is no rotor-to-rotor or rotor-to-casing contact. Low pressure on stuffing boxes provides easy servicing.

Horizontal or vertical models to handle 32 to 500,000 SSU, 1 to 550 GPM at 250 PSI for viscous liquids, 50 PSI for water. Corrosion-resistant alloys, steam-jacketed bodies, water-cooled bearings, other adaptations to meet individual needs. See "Yellow Pages" for your local Sier-Bath Pump Representative or send for Bulletin G-2. *Sier-Bath Gear & Pump Co., Inc., 9261 Hudson Blvd., North Bergen, N. J.*

Sier-Bath ROTARY PUMPS

Screw Pumps **Gearex® Pumps** **Hydrex® Pumps**

Founded 1905 **Mfrs. of Precision Gears, Rotary Pumps, Flexible Gear Couplings** **Member A. G. M. A.**

Building . . .

types out what it is doing, and sounds an alarm if any part of the system shows signs of impending danger or failure. It must analyze incoming gases, measure pressures, rate of flow, and temperatures, relate these to both in-put and out-put, and keep an eye on the condition and activity of the catalyst materials used. It then evaluates all these variables, makes a judgment in the light of its mathematical model for maximum efficiency at the moment, and resets the plant's control to conform to this judgment every 5 minutes, 24 hours a day. Savings from more efficient use of catalyst materials alone are expected by the company to be around $75,000 per year.

Shell Oil Co. has almost completed construction of gathering lines, compressors and a liquid-recovery unit at its Big Foot field, Frio and Atascosa Counties, Texas. The dry-bed recovery unit is expected to yield about 100 bpd of liquid hydrocarbons. Gas will be compressed to pipe line pressure by five compressors totaling 1,325 horsepower. The unit will deliver about 7 MMcf of dehydrated casinghead gas daily to Transcontinental Gas Pipe Line Corp. About 42,000 feet of new gathering lines are being built in the field, adding to an existing 14,000-foot gathering system. Checking drawings on the liquid recovery unit visible in the background are engineers from Black, Sivalls and Bryson, Inc., and Shell.

The Carter Oil Co. is adding LPG facilities at its Billings, Mont., refinery in the second extension of major work in less than a month. New construction will include addition of a 560-bpd deethanizer tower to an alkylation unit now nearing completion, propane tank storage and a five-spot car-loading rack with pumping facilities to handle isobutane charge for the alky unit.

The Refinery Engineering Co. will design, engineer, construct and handle purchasing for the jobs, and is also prime contractor on alkylation and other major facilities. Treco was contractor on a new asphalt emulsification unit and revamp of the road-oil plant last month. All work is at Billings.

Construction on the deethanizer column will be completed by early July.

For more data on advertised products, use Readers' Service Cards, last page.

fast, high pressure hot taps

MUELLER®

CH-6 drilling machine

Make fast automatic cuts under pressures up to 1440 p.s.i. with the Mueller CH-6 Drilling Machine.

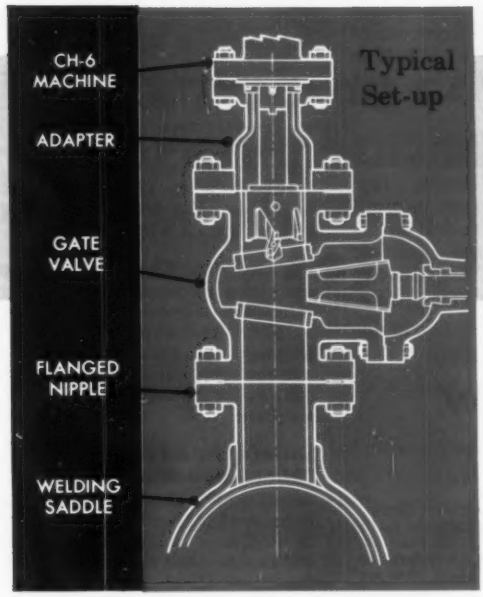
High pressure lateral connections may be quickly completed to any line or tank by using the CH-6 Machine and a high pressure gate valve. Simply weld a hat flange or drilling nipple to the line or tank, bolt the gate valve to it, and bolt the CH-6 Machine to the valve.

The CH-6 Machine may be operated by hand or by an air motor or gasoline engine power unit without changing the machine. Automatic power cutting does not require supervision during the cutting operation.

The adaptability of the CH-6 Machine makes a great variety of nipple and valve combinations possible.

Write for complete information.

CH-6 Machine with air motor power unit making hot tap through high pressure steel gate valve.



SPECIFICATIONS

- Cuts from 2" through 6".
- 1440 p.s.i. maximum working pressure at 100° F.
- 500° F. maximum temperature rating at 1250 p.s.i.
- Adapters available for use with valves having 150, 300, 400 and 600 pound flanges.

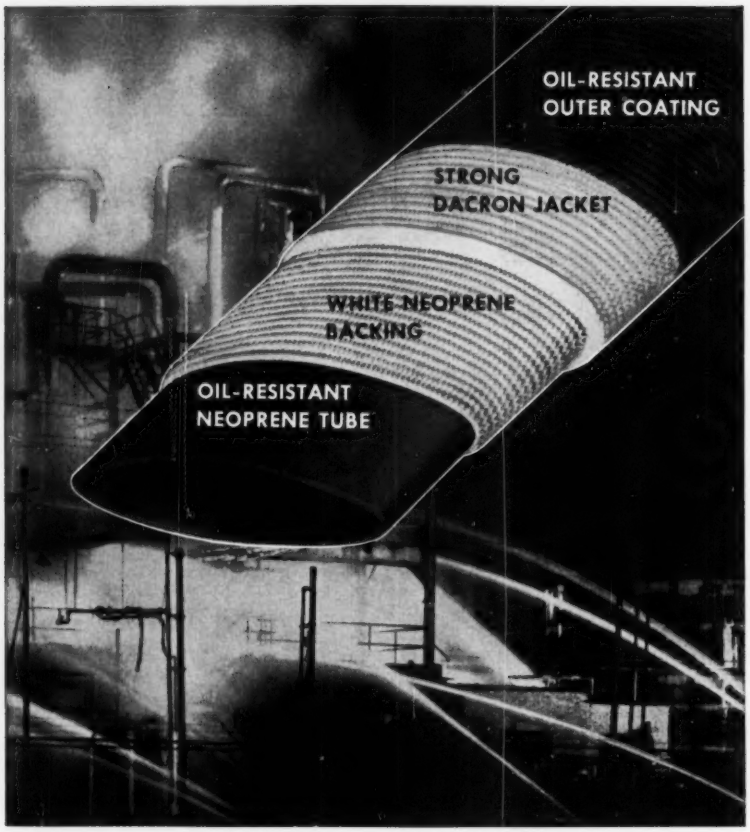
NO-BLO®

MUELLER CO.
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario

For more data on advertised products, use Readers' Service Cards, last page.

YEARS OF CHEMICAL EXPOSURE CAN'T KNOCK OUT THIS PETROCHEM FIRE HOSE



Strong, lightweight, extremely flexible, and easily folded, "Quaker" PETROCHEM is ideal for fire-protection where acids, alkalies, and hydrocarbons ruin ordinary hose.

Many large chemical plants (typical case histories on request) report PETROCHEM hose still going strong after as long as *four years'* constant exposure to sulfur, chlorine, solvents, etc., where hose previously had to be replaced two or three times a year.

Neoprene inner tube and neoprene-impregnated "Dacron" jacket give PETROCHEM maximum corrosion-resistance. *And PETROCHEM is the only all-synthetic fire hose with UL approval.*

Ask the Thermoid industrial distributor about PETROCHEM "White" and PETROCHEM "Black" fire hose to meet the severest requirements of the oil and chemical industries. Or write *Thermoid Division, H. K. Porter Company, Inc., Tacony & Comly Sts., Philadelphia 24, Pa.*

THERMOID PORTER DIVISION

H.K. PORTER COMPANY, INC.

HERE'S HOW PORTER SERVES INDUSTRY: with Rubber and Friction Products—THERMOID DIVISION; Electrical Equipment—DELTA-STAR ELECTRIC DIVISION, NATIONAL ELECTRIC DIVISION; Copper and Alloys—RIVERSIDE-ALLOY METAL DIVISION; Refractories—REFRACTORIES DIVISION; Electric Furnace Steel—CONNORS STEEL DIVISION, VULCAN-KIDD STEEL DIVISION; Fabricated Products—DISSTON DIVISION, FORGE AND FITTINGS DIVISION, LESCHEN WIRE ROPE DIVISION, MOULDINGS DIVISION; and in Canada, Refractories, "Disston" Tools, "Federal" Wires and Cables, "Nepcoduct" Systems—H. K. PORTER COMPANY (CANADA) LTD.

Building . . .

The column will remove all ethane and lighter components before feeding the depropanizer column and alkylation unit contactor. The depropanizer will take its feed from the bottom of the deethanizer tower, along with additional stripper bottoms from the alkylation unit.

Texas City Refining Inc. has placed a 7,000-bpsd catalytic reformer on stream at its Texas City, Texas, refinery. The new unit has built-in flexibility for processing a wide variety of naphtha feed stocks to produce high octane gasolines. It consists of three catalytic reactors plus an integrated pre-treat catalytic guard-reactor for feed stock purification. Process design for the reformer was furnished by Houdry Process Corp., while engineering and construction was done by Catalytic Construction Co.

Gulf Oil Corp. has completed a new alkylation unit at its Toledo, Ohio, refinery. The new facilities will combine light hydrocarbons created in other refinery operations, to produce about 2,000 bpd of alkylate. The new unit has a reactor section and four distillation towers, the tallest of which is about 170 feet. Sulfuric acid catalyst is used to promote alkylation reaction.

The M. W. Kellogg Co. handled engineering and construction on the Toledo alkylation unit—Gulf's first to use gas-fired reboilers.

British American Oil Co. has begun a $4-million expansion of processing facilities to increase capacity of its gas processing and sulfur plant at Pincher Creek, Alta. Ralph M. Parsons Construction Co. of Canada Ltd., which built the initial two stages of the plant, will handle construction.

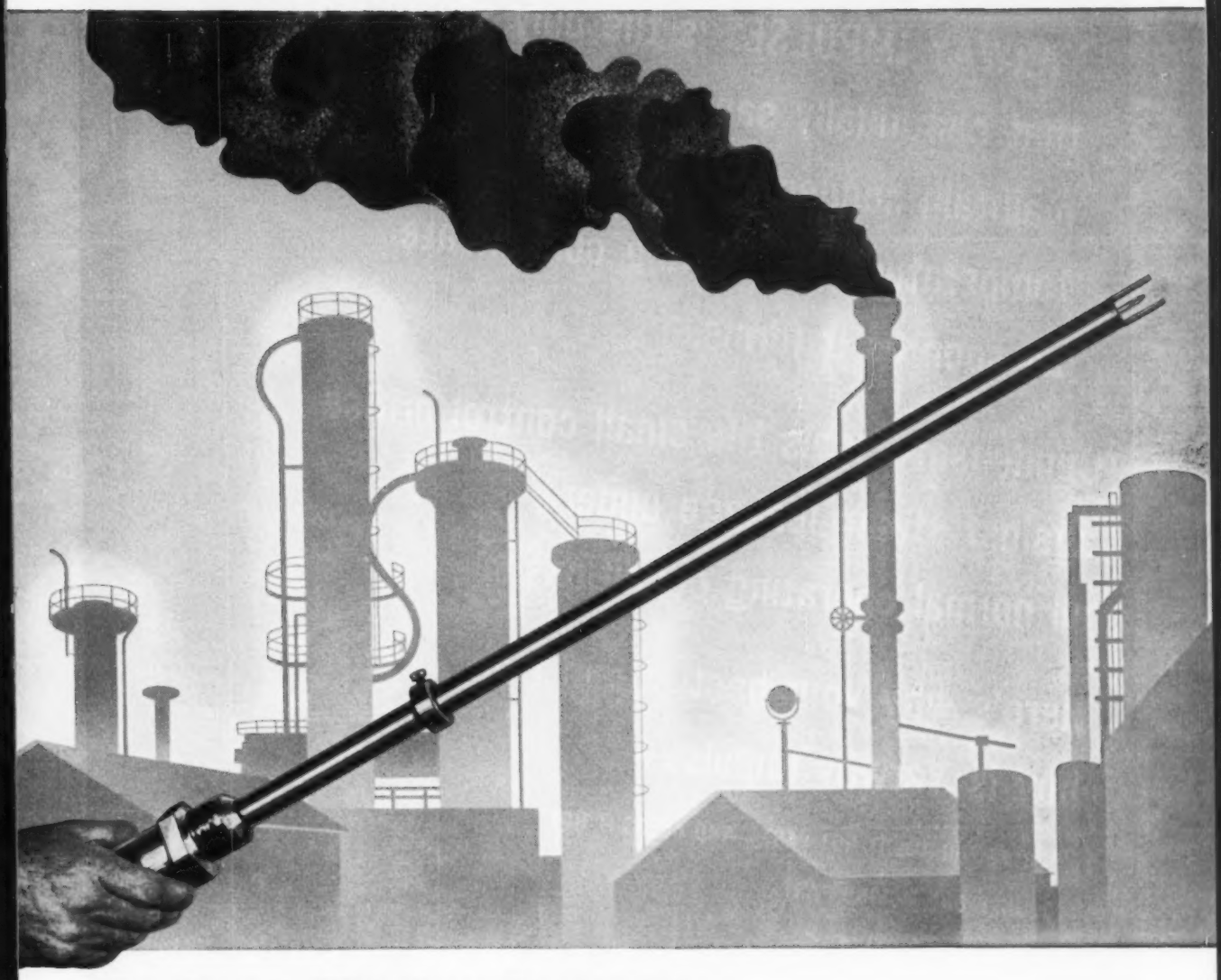
Stage three will raise daily raw gas capacity from 120 to 180 MMcf and further increase production of propane, butane and condensate. It will also enable all three of the sulfur units to operate at full capacity of 675 long tons a day.

Consolidated Mining and Smelting Co. will build a $5 million, 36,000-ton-per-year urea plant in Calgary, with completion slated for 1960. To be Canada's second urea unit and the first in Western Canada, the plant will manufacture high-purity prilled or pelleted products, or special solutions.

Wyandotte Chemicals Corp. has completed reconstruction of its ethylene-oxide and ethylene-glycol plant, damaged by a fire and explosion last year. The Geismar, La., plant, near Baton Rouge, was the first unit to startup at the company's new chemical manufacturing center there.

Societe Anonyme des Produits Chimiques Saint-Gobain has gone on stream with a chemical plant complex at Berre, near Marseilles, next to Compagnie de Raffinage Shell Berre. The facilities will enable Shell Saint Gobain, in which the Royal Dutch Shell Group has a 60

Thousands going up the stack?



Reduce Flaring Losses
Control Air Pollution
with the "Anemotherm" Probe-Type Gas Flow Meter

You can stop profits from going up the flare stack with the new "Anemotherm" *Probe-Type* Gas Flow Meter. This *electronic, stainless steel* instrument quickly locates points of loss . . . accurately measures gas flow from 10 to 15,000 FPM with a scale range of 500 to 1. Refineries report savings of thousands of dollars per day.

The new "Anemotherm" Gas Flow Meter offers many exclusive features. Sixteen probe meters can be connected to one strip recorder so that flow in sixteen process lines can be observed and recorded by one instrument. The probe is self-compensating for ambient temperature and can be used in gas streams to 300°F. The probe has fast response, is corrosion resistant and streamlined. Accuracy is ± 5% of meter reading. The "Anemotherm" Gas Flow Meter is easy to install and easy to clean.

Look into the money-saving accuracy and efficiency of the "Anemotherm" Gas Flow Meter. For complete engineering data send for Technical Bulletin 5000.

ANEMOSTAT®

ANEMOSTAT CORPORATION OF AMERICA

10 East 39th Street, New York 16, N. Y.

Representatives in Principal Cities

AC1369

YARWAY IMPULSE* is the only steam trap that continually samples fluid in the line to maintain condensate discharge close to steam temperature, eliminating condensate as soon as it forms.

Condensate seals the small control orifice against steam leakage under all normal operating conditions.

Here's why your best steam trap buy is Yarway Impulse—

1. GETS EQUIPMENT HOT FAST—AND KEEPS IT HOT
2. ONLY ONE MOVING PART
3. LOW MAINTENANCE
4. SMALL SIZE—LIGHT WEIGHT
5. GOOD FOR ALL PRESSURES
6. NON-FREEZING
7. COMPLETE LINE FOR EVERY REQUIREMENT

ONLY ONE MOVING PART, A SMALL STAINLESS STEEL VALVE, ACTUALLY "FLOATS" ON THE CONDENSATE LOAD.

Actual size ¾" trap

* . . . A COMPLETE LINE OF STEAM TRAPS, ALL OPERATING ON A PROVEN THERMODYNAMIC PRINCIPLE.

SEE OUR EXHIBIT
MAY 14-23, 1959
Tulsa, Oklahoma

YARWAY impulse®

Manufactured by YARNALL-WARING CO., 128 Mermaid Ave., Philadelphia, Pa.
Stocked and sold by 270 Industrial Distributors
Write for free bulletin "The Why and How of Steam Trapping"

Building . . .

percent interest, to produce resins and base materials for carbon black and detergents, and expand production of organic solvents.

British Petroleum Co. and Shell Oil Co. (Mexico) are said to be considering construction of a refinery in Northern Ireland. Negotiations are reportedly underway between the government and companies.

Southern Nitrogen Co. has almost completed its ammonia-plant expansion at Savannah, Ga. In addition to this 20-25 percent increase the company will begin producing solid nitrogen material containing 20.5 percent nitrogen plus dolomitic limestone, and solid urea for chemical and animal feed applications.

Union Rheinische Braunkohlen Kraftstoff AG plans to have a new 25,000-ton-per-year urea plant in production early in 1960 in Wesseling, near Cologne. The company will supply its own ammonia and carbon dioxide.

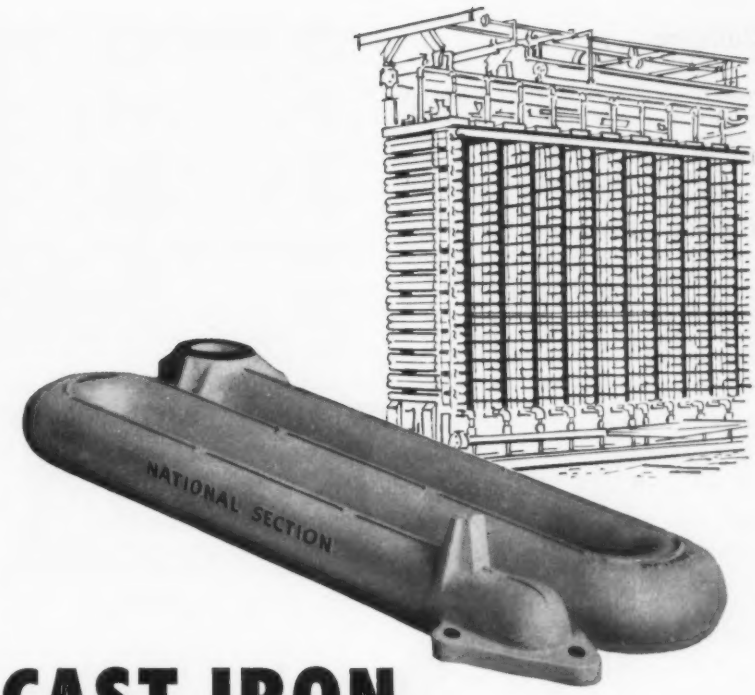
Fertilizers and Chemicals, Ltd. (Haifa) plans a $6.7-million expansion in Israel that will double nitrogen facilities and provide capacity for liquid and compound granulated fertilizers. The company foresees a rise in ammonia output to 20,000 tons per year by 1960, and an eventual increase to 26,000 tons.

Copolymer Rubber & Chemical Corp.'s expanded rubber plant at Baton Rouge is producing 6-million additional

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd Federal and Dearborn Streets, Chicago 16, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the registry.

Cyclobutane
5.5-Dimethylcyclopentadiene
Tetradecylmethyl ketone
1-Methylcyclobutene
1,1,1-Trichloro-2-propanol (Isopral)
p-Nitrobenzenediazonium p-toluene sulfonate
Propane-1,3-dithiol-2-carboxylic acid Chloramide
N,N'-Dimethyl-decahydro-2-naphthylamine
Perchlorocyclohexane
Perchlorocyclohexene
2,2'-Thiobis(4-chloro-6-methyl phenol)
N-(2-Naphthyl)phosphoramidic acid
Hexadecylmethyl ketone
3-Hydroxy-4-methoxycinnamic acid (Isoferulic acid)
2-Isocyanatopropane
β,β,β-Trichloroborazole
2,3'-Bipyridine
Pentachlorocyclopentadiene
3',3",5',5"-Tetrabromophenolphthalein ethyl ester, potassium salt



CAST IRON FOR COOLING CORROSIVES

National-U.S. Cast Iron Sections are the most widely used heat transfer units for sulfuric acid cooling in sludge recovery and contact plants—and have been, for many years. More and more, process engineers are looking into the possibility of using these units for other acids and corrosives in the chemical and petrochemical industries.

National-U.S. engineers can contribute valuable help from this background of experience in these fields. Call on them when you have a problem of heating or cooling corrosive materials in your operation.

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For more data on advertised products, use Readers' Service Cards, last page.

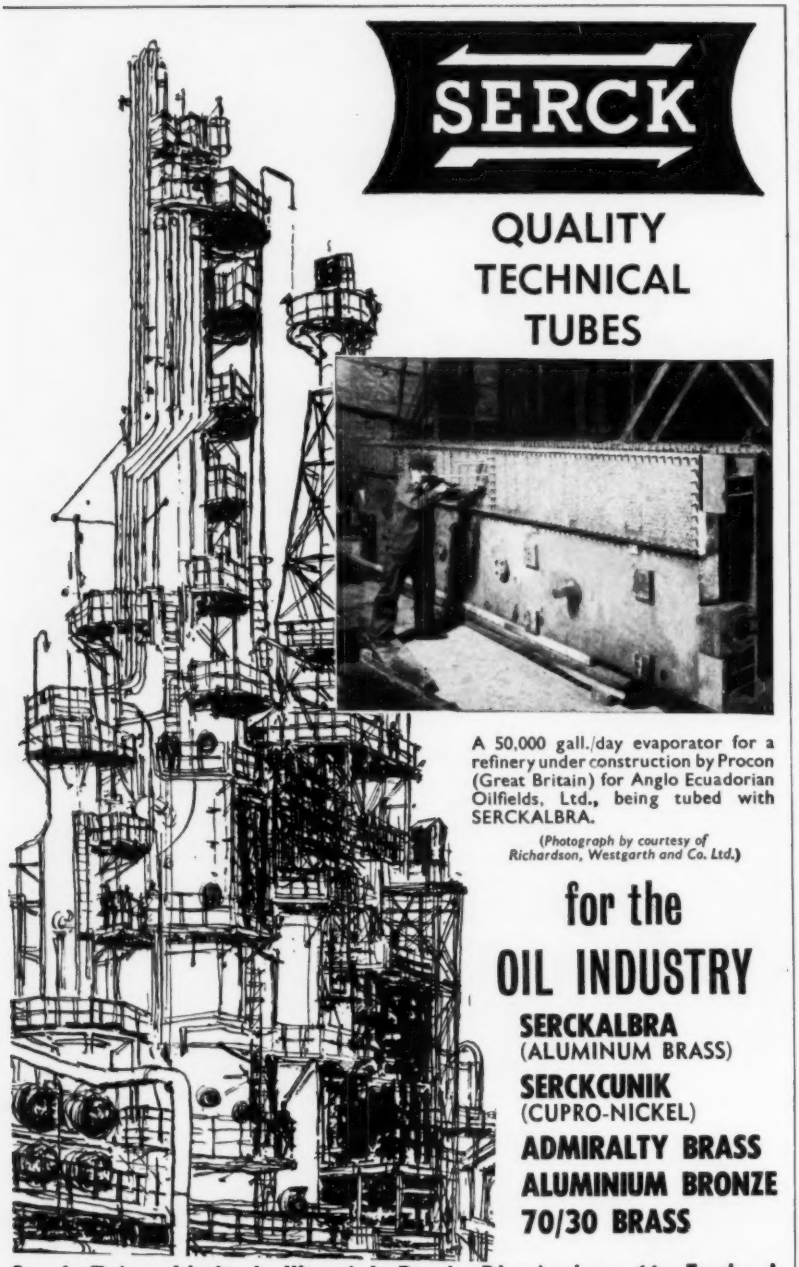
Building . . .

pounds per month of GRS rubber, increasing the company's synthetic rubber potential to 18 million pounds per month. The new line ran at 80 percent capacity in April—is expected to hit full output this month.

Yugoslav Rudnap Co. and Montecatinni Co. plan to build an $8.5-million fertilizer plant at Lukovaz. The plant would produce 380 tons per day of ammonium nitrate, 340 tons per day of nitric acid and 100 tons per day of ammonia.

Derby Refining Co. is planning a $700,000 waste-water abatement project at its Wichita, Kan., refinery. The project includes a waste disposal unit, storm water collection system, and new process sewer system. Slated for completion this month, construction is being handled by Kaighin-Hughes-Litwin, Inc.

Chemstrand, Ltd., has gone into production with its $9-million acrylic fiber plant at Coleraine, County Londonderry, Ireland. The 10-million-pound-per-year plant will provide fibers for the Irish textile industry.



SERCK

QUALITY TECHNICAL TUBES

A 50,000 gall./day evaporator for a refinery under construction by Procon (Great Britain) for Anglo Ecuadorian Oilfields, Ltd., being tubed with SERCKALBRA.

(Photograph by courtesy of Richardson, Westgarth and Co. Ltd.)

for the OIL INDUSTRY

SERCKALBRA (ALUMINUM BRASS)

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ADMIRALTY BRASS

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70/30 BRASS

Serck Tubes Limited, Warwick Road, Birmingham 11, England

Mobile International Oil Co. has awarded the engineering contract for a 65,000-bpd refinery at Mersin, Turkey, to Foster Wheeler Corp. Work on the $50-million project will begin in about six months and be completed late in 1961. To be operated by Anadolu Tasfiyehanesi, a Turkish company, the plant will include crude distillation, catolytic reforming and kerosine desulfurization units. Produced will be gasoline, kerosine, diesel fuel and heavy fuel oil.

Columbia Hydrocarbon Corp. has completed its new fractionating plant at Siloam, Ky., on the Ohio River. Initial annual capacity for the dual-phase operation is 105 million gallons of ethane, 68 million gallons of propane, 23.7 million gallons of butane and 10.5 million gallons of natural gasoline. The plant's ethylene potential is 350 million pounds per year. At present ethane is separated and returned to the natural gas stream. Most of the butane will be used to upgrade the gasoline and the balance, along with the propane, will head for LPG markets.

Poland plans to build a 2-million-ton-per-year refinery at Plock, 25 miles west of Warsaw. Construction will begin in 1960. The refinery would be the basis for a domestic petrochemical industry.

Imperial Oil Co. will build a $2.4 million alkylation plant at its Edmonton, Alta., refinery, with a capacity of 1,500 bpd of alkylate. Construction should begin in September and the unit will in operation by April, 1960.

Gulf Italia Oil Co. is building a 10,000-ton-per-year, $18-million petrochemical plant at Ragusa, Sicily. The project, to produce plastics, will start up late this year.

Best Fertilizer Corp. has completed its new ammonia plant at Lathrop, Calif. It reportedly is producing 125-130 tons per day.

Shell Refining & Marketing Co. has completed an 80,000-bpd distillation unit at its Shell Haven, England refinery. Capacity of the plant was increased to 160,000 bpd.

Spencer Chemical Co. is upping capacity at its Orange, Texas, polyethylene plant, work on the high-pressure unit is slated for completion by Summer, 1960. Figures on the increase at the 90-million pound-per-year plant have not been revealed.

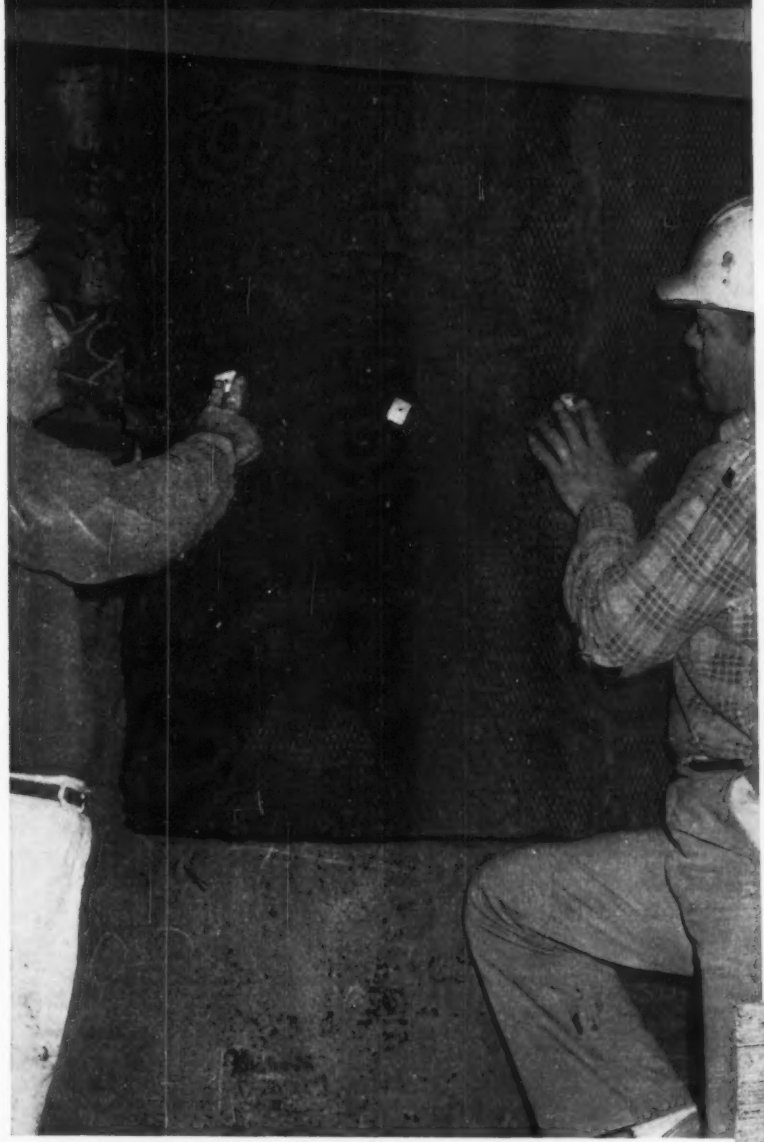
Solid Nitrogen Co. has been formed by a group of investors, and plans to build an ammonia-urea plant at Freeport, Texas. Chemical Construction Co. has been announced as probable constructor of the $10-million project.

Batzer Oil Co. has sold its Lovell, Wyo., refinery to Husky Oil Co., Cody, Wyo. The refinery was closed in March and is presently being dismantled. Husky plans to use the equipment in its expansion program at Cody.

Esso Standard S.A.F. has completed a 32,000-bpd refinery near Bordeaux, France. The plant will process crude oil from small fields in southwestern France.

For more data on advertised products, use Readers' Service Cards, last page.

B-H Blanket Insulation withstands vibration on....



Coke Drum at MOBIL OIL CO. Paulsboro Refinery

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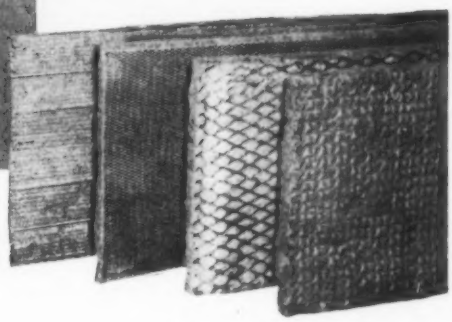
For installation of Baldwin-Hill Blankets and other efficient B-H industrial insulations, request contract application service (available in 48 States) and watch the costs go down.



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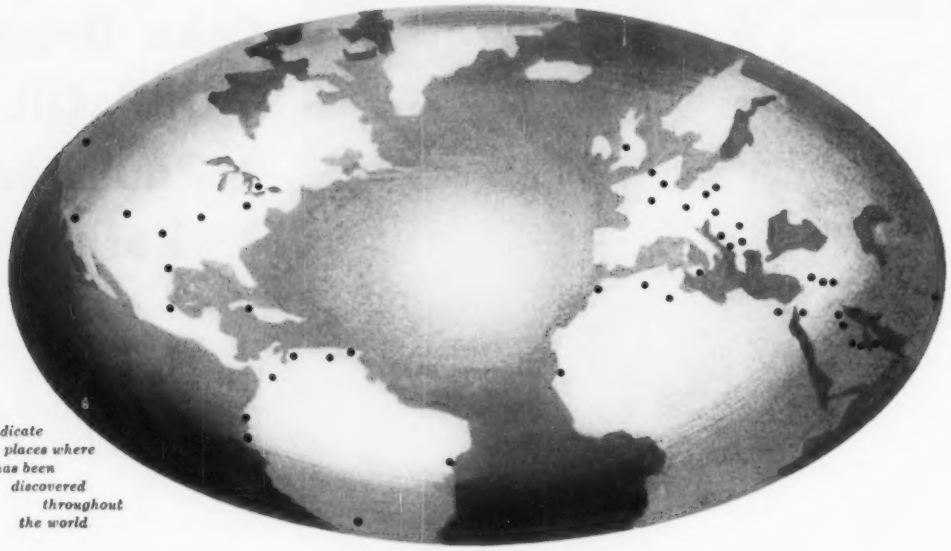

Dots indicate places where oil has been discovered throughout the world

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A Staff Report

Find Out Why Employes Quit!

One way of doing this is with an "exit interview." This valuable technique will unearth any "hidden" personnel problems and may enable you to salvage valuable employes who are ready to resign

ONE OF THE best methods for helping solve personnel problems such as turnover, low morale and chronic complaints is seldom used by some companies and never used by others. This method is the exit interview.

An exit interview is one that takes place between the employe and a member of management as soon as possible after the employe reveals that he intends to leave, or when management decides to discharge him. Valuable information can be gathered in the exit interview that can contribute to the smooth running of any industry. It will also provide a control to help prevent future turnover and employe unrest.

Whether a person is leaving voluntarily or is being released, an exit interview should be held. Many potential quits can be salvaged and it will also permit management to get to the roots of any problems involved.

Many times an employe does not know the real reason for quitting his job. A sound means of ascertaining the real reason is provided by a carefully conducted exit interview.

Advantages. To some members of management, holding an exit interview seems to be a waste of time. Nevertheless, if properly conducted, the interview will more than pay its way by providing the following benefits:

1. Determines the true reasons why employes are leaving the company.

2. Persuades desirable employes to give their resignations a second thought and perhaps change their minds about leaving. Many valuable and competent employes may be retained by reaching a satisfactory agreement on their problems.

3. Permits the company to clarify its position and reasons when the employe is being discharged.

4. Gathers valuable and reliable data which can be used as a basis for correcting any situation that is contributing to turnover and employe unrest.

5. Does a good public relations job. Even though the company is losing an employe, it wants to retain a customer.

The interview will permit the employe to "get it off his chest" and find welcome relief, and regardless of whether he contributes anything worthwhile, he will leave with a better feeling toward the company and its management.

Who Does the Interviewing? It might be more appropriate to ask, "Who does not do the interviewing?" Because of the complexity and importance of the exit interview, those who have been failures elsewhere should not be assigned the task. By the same token, those who have basic personality problems of their own or those with limited conversational and perceptual ability, should steer shy of this important undertaking.

It is also unwise to assign anyone

who looks upon it as just another job and does not recognize its real demands for professional understanding.

There is complete agreement among professional interviewers that the most important prerequisite for a successful exit interview program is selection of the right interviewer.

Qualifications of Interviewer. It almost goes without saying that it is difficult to find a man with all the ideal qualifications. Chances are, however, that a much better selection job can be done by using a set of basic qualifications as a yardstick.

The first step in seeking the right person, or persons, is to eliminate all personnel who do not have a thorough knowledge of the jobs throughout the company. The success of the exit interview depends largely on the interviewer's experience with people in general, his job knowledge, and his familiarity with the kinds of people needed in the jobs.

Where employe counseling services are available in the company, the counselors should conduct the interviews. This means that the exit interview activity would be set up as a separate function, with no connection with other departments except those concerned with personnel administration.

Where there is no counseling service, it is likely that personnel specialists, who have greater experience with a variety of people than line officials, would be more qualified to do the interviewing. After selecting the few candidates that meet the above requirements, the individual should be evaluated in the light of the following personal qualifications:

1. Should Know How to Obtain Basic Facts. Also how to determine the real meaning behind statements. Many employes often hesitate to give the interviewer the real reason, or reasons, for leaving. In addition, many do not understand what is causing their job dissatisfaction and cannot truthfully give the real reasons.

It follows, then, that the exit interviewer must have a quick mind and a well-integrated empathetic ability. He must be able to "read between the lines" and "put himself in the employe's shoes."

2. Should Have a Stable Personality. A mature personality is of the essence here. People with extreme opinions and biases on everyday and company matters should be rejected. They lack the objectivity and humility which are fundamental to success.

Very careful screening should be done because these people are the kind who welcome the opportunity to be an exit interviewer, and they may be selected because of this eagerness.

Sufficient maturity and poise will lend validity to the judgments rendered and promises made to the employe.

3. Ability to Enlist the Aid of Others. The exit interviewer needs to gather pertinent information and solicit cooperation from people who are closely associated with the employe. This would involve supervisors, union personnel and people from closely related departments.

A thorough knowledge of human relations and "how to get along with others" would help fill this requirement. Those who associate with and have experience with persons who have a variety of backgrounds and characteristics are prone to have this knowledge.

4. Ability to be Objective. Warmth and kindness is needed to establish rapport with an employe, but "cold-blooded objectivity" is an essential attitude for the exit interviewer when he analyzes the data involved.

On the other hand, he must not be sadistic or power mad. Since he is in a position of authority he has ample opportunity to be mentally cruel through lecturing, scolding and raising false hopes in the employe.

He should never give the impression that he is an "informer" or that any statements made will be held against the person. He should remain objective and accept all criticism with appreciation.

5. Not Overtalkative. An overtalkative person will generally do more harm than good. In the first place, he will waste all available time needed to obtain valuable information.

Secondly, while a person is talking he cannot be observing and interpreting. Also, he is more prone to "put his foot in his mouth" and perhaps intensify the employe's dissatisfaction.

A good rule to use here is to obtain a good listener and not a fast talker.

6. Knowledge of Company's Organization, Products and Personnel Policies. Again it might be presumed that personnel specialists, because they work closely with many different kinds of jobs, may have a more thorough knowledge and broader viewpoint in this regard than operating officials.

In any case, it is obvious that the interviewer needs this essential knowledge.

7. Knowledge of Company and Community Services. It is well known that home conditions affect the job and must be considered with job problems since both exist in the same person.

A thorough knowledge of company and community services may be of help in solving the problem that is forcing the employe to resign. Many times the employe is unaware of these services and is more than glad to stay on the job and let the services solve his personal problem.

8. Experience as an Interviewer. It takes considerable experience to be a proficient exit interviewer, and while all must start sometime, an interviewer with past experience is better than one without such experience.

The past experience, however, must have been of high quality and at least moderately satisfactory. The adage that "practice makes perfect" isn't necessarily true. The adage should be: "*Correct* practice makes perfect."

Many so-called experienced interviewers are of poor quality because they have been unknowingly using poor methods and techniques. This fact may support the contention of many members of management who feel that it is better to appoint an inexperienced interviewer and train him properly from the beginning.

This would eliminate the possibility of using an "expert" interviewer who has, over the years, merely perfected his fumblings and blunders.

Qualifications Utopian. There's no denying the fact that these qualifications are Utopian. In most cases

then, compromises will have to be made. But remember, the more compromises, the weaker the interviewer, and the greater the need for instruction and training. Exit interviewing is too important a job and too refined a method to be left in the hands of the inefficient.

To repeat, the success of the exit interview depends upon the quality of the interviewer. Also, interviewer quality is a direct measure of how extensively to use the interview and how much weight to give it.

Established Records and Procedures. The worth of the exit interview is lessened when all employes are not interviewed prior to their leaving and when accurate, workable records are not kept.

Each interview report should be recorded in the employe's personal file as well as in the interviewer's central file. It is from these reports and records that valuable data will emerge, and from this data will come future control of turnover, complaints and other personnel problems.

The effectiveness of the exit interview program will be enhanced by installing and maintaining a system by which employes can be routed to the interviewer. Some definite company procedure for arranging a meeting between the employe and the interviewer as soon as the employe expresses a desire to leave should be established. The interviewer, after being notified of the proposed meeting, should schedule it at a date which would allow ample time to obtain necessary information.

Preparation. Advance preparation of the exit interviewer is absolutely necessary if the program is to be successful. First, the interviewer must gather adequate background data on the employe. Then he must analyze all available information concerning the employe's personal history, work performance, and working conditions. The interviewer should become familiar with the efficiency ratings, production records and grievance history.

The employe's supervisor should also be consulted at length. His suggestions and recommendations for disposition of the case must be recorded and considered.

Physical Facilities. An important responsibility of the interviewer is to provide a proper meeting place. For the room or office may have a psychological effect upon the success of the interview.

The interview should be held in a reasonably dignified, private place that is familiar to the employe. This will permit him to feel at ease and talk without fear of being overheard.

The interviewer should take steps to provide proper ventilation, insuring against drafts, heat and disagreeable odors. Unnecessary noises and confusion should be eliminated. The sound of machinery, telephone conversations, typewriters or slamming doors are all causes of serious distractions.

There should be comfortable chairs, drinking water and sufficient light. Ample room should be provided for the employe if he wishes to stand and walk about.

Recording Accurate Information. The recording of full, accurate and relevant information is of primary importance. However, it must be done so in sufficient detail as to be used to promote employe adjustment and reduce turnover.

Keeping notes will facilitate matters because it shows the employe that his statements are important enough to record. He must be made to understand, however, that the statements will not be held against him if he remains or if a letter of recommendation is written to a prospective employer.

The interviewer should refrain from conducting the interview in a stereotyped manner by checking, in a routine, cut-and-dried way, the reasons for leaving. Such actions convince the employe that the interviewer and company are really not interested in his story and therefore he doesn't care to produce much information.

One Side. It is of paramount importance that the interviewer realize that the employe is "telling his side of the story." A great deal of his story is no doubt true, but, the interviewer must be constantly alert for digressions, pauses, untrue statements, and attempts to divert the discussion.

One means of ascertaining the truthfulness of a statement is for the interviewer to make unjustifiably favorable remarks about the employe's motives or unfavorable comments about those with whom he has been in conflict. In such cases, the truthful employe will correct and tone down what the interviewer said.

A better method, and one more easily used, to obtain full and accurate information is for the interviewer to have a "permissive" attitude. The employe will then feel that he is not being criticized and that he can express his feelings without danger.

Ask Pertinent Questions. After the employe has made his statements, the interviewer should ask appropriate questions to determine the true reasons for the employe's unhappiness. This will facilitate a satisfactory solution to his problem and supply specific data needed to bring the interview to an effective conclusion.

Such questions would include asking about: 1. The specific conflict situation so the employe's answers can be compared with his supervisor's statements

2. The possibility of the employe transferring to another department or taking special training so he may be promoted

3. The problems he will encounter upon leaving. This could lead to ways that he might adjust himself to present conditions.

Closing the Interview. The close of the interview is as important as the beginning. The parting must be on a friendly basis even if there has been emotional outbursts during the interview. Try to close the interview while the employe is thinking positively. It is unwise to close while he is thinking negatively and making statements that he would never change for fear of losing face. Also, be sure there is a mutual understanding of any agreements reached.

This discussion shows that an exit interview program has weaknesses and strengths. When well formulated, however, it provides sufficient information for sound records which can be used for analysis and control of employer-employe problems.

##

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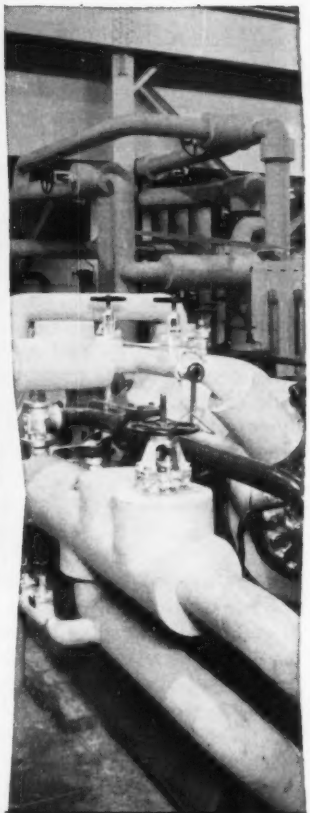

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INSULATION GUIDE

Temperature	Recommended Pabco Insulation
to 850° F.	85% Magnesia pipe covering • block • cement
to 1200° F.	Caltemp pipe covering • block • cement
to 1500° F.	Prasco 19 C pipe covering • block • cement
to 1900° F.	Prasco 19 C block

For more data on advertised products, use Readers' Service Cards, last page.

Inert Gas + Poor Piping = Explosion

Here's what Polymer Corporation found out about storing dilute butadiene

D. S. Alexander and C. M. Finigan
Polymer Corporation, Ltd.

AT 9:05 A.M., June 3, 1958, an explosion occurred at Polymer Corporation in the piping above a storage drum containing dilute butadiene. A production supervisor arrived at the scene approximately one or two minutes after hearing the explosion and observed a brownish, grey, "smoke" above drum D-66. Other eye-witnesses said the "smoke" was more of a light-grey color.

The control valve regulating D-66 pressure is part of a 2-inch line leading to the east flare as shown in Figure 1. At Points 1, 2 and just left of the pressure control valve at Point 5, the line was severed and forcibly hurled into the fencing above the catwalk above drum 66.

The supervisor observed a lazy sort of flame above the break at Point 1 and the other points of rupture were smoking. The line to the flare from the ruptured flange was apparently displaced violently to the right, thus the pipe occupied the approximate position indicated by the dashed line shown under "platform" in the diagram.

Slow Explosion. The open end of this line was plugged with a wooden plug to prevent the outbreak of a serious fire, since gas was escaping from the flare line at this point. The bolts tying the flange together at Point 2 were stretched before giving away (Figure 2) and one bolt was found 200 feet away by a storage sphere. It must have rebounded from another sphere to have come to rest in this particular spot. The piping was stretched before rupture, as shown in Figure 3 indicating a slow explosion.

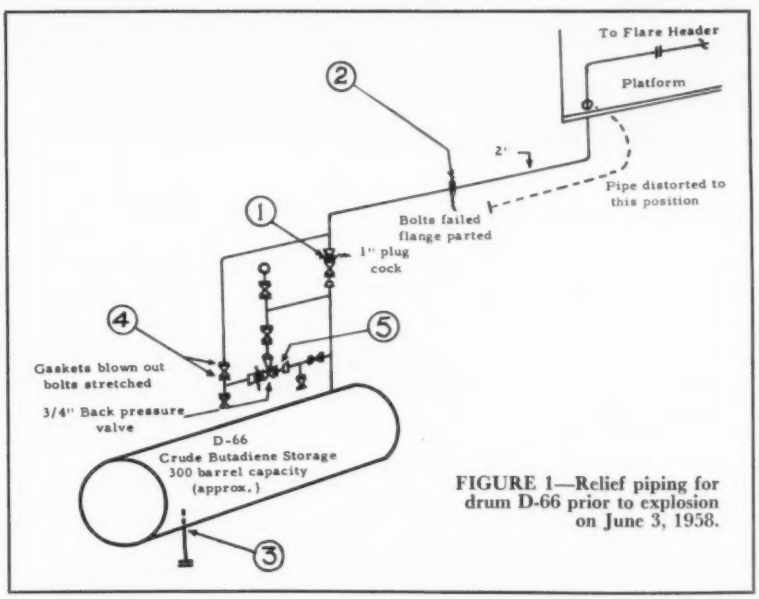


FIGURE 1—Relief piping for drum D-66 prior to explosion on June 3, 1958.

The line at Point 3 in Figure 1 was normally used for loading and unloading D-66. The drum contained approximately 120 barrels of 50 percent butadiene from a tank car which had been unloaded May 26 and partly displaced on May 27.

Due to the low capacity of the pump, it was standard procedure to pressure D-66 with "inert gas" before pumping it out. The unloading operation was started then curtailed because of problems in the receiving area. Therefore, the drum and its contents were left in this static, partly-emptied condition from May 27 up to the time of the explosion (one week).

The control valve at Point 5 was found properly closed after the explosion. The hydrocarbon in D-66 was purged immediately and 10 or 12 drums of toluene followed by cold caustic solution were added to the drum. This mixture was then gradually displaced to another drum for disposal.

Laboratory Data. Table 1 shows a summary of laboratory analyses.

Oxygen contents of the inert gas and D-66 vapor were obtained with the mass spectrometer and are considered accurate to ± 0.05 percent. Active oxygen analyses on solid and/or oil material were obtained

FIGURE 2—Stretched and ruptured flange bolt.

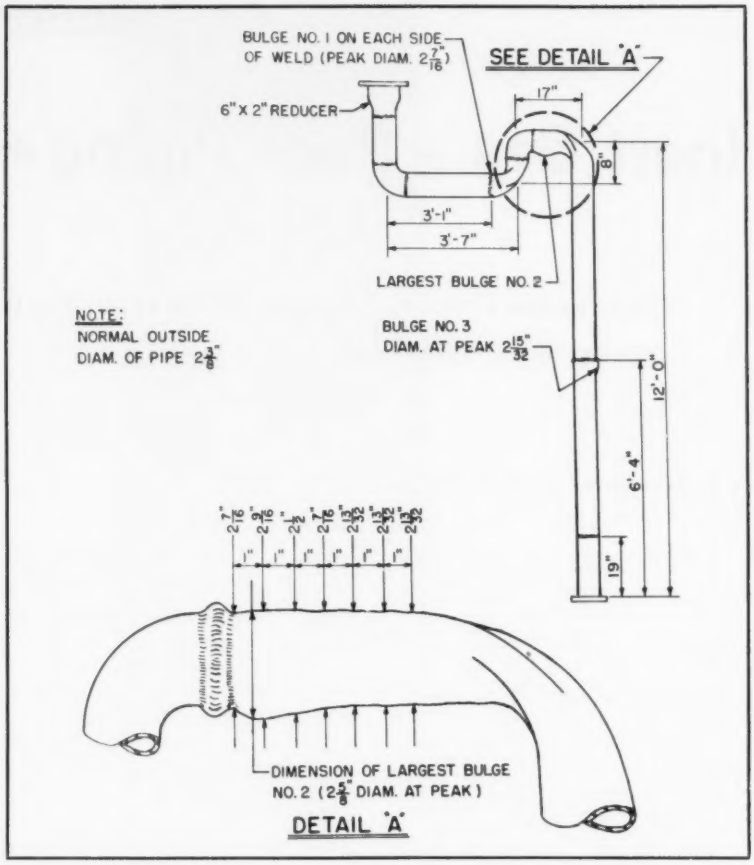

BULGE NO. 1 ON EACH SIDE OF WELD (PEAK DIAM. 2 7/16")
SEE DETAIL "A"
6" X 2" REDUCER
17"
8"
3'-1"
3'-7"
LARGEST BULGE NO. 2
NOTE:
NORMAL OUTSIDE DIAM. OF PIPE 2 3/8"
BULGE NO. 3 DIAM. AT PEAK 2 15/32"
12'-0"
6'-4"
16"
2 7/16" 2 9/16" 2 1/2" 2 7/16" 2 13/32" 2 15/32" 2 29/32"
1" 1" 1" 1" 1" 1"
DIMENSION OF LARGEST BULGE NO. 2 (2 5/8" DIAM. AT PEAK)
DETAIL "A"

FIGURE 3—(right) Section of 2-inch pressure release line removed after explosion.

by extracting the samples with glacial acetic acid, adding two milliliters of saturated potassium iodide solution and ten millilitres of concentrated hydrochloric acid to 25 millilitres of the extract, refluxing for exactly five minutes, and titrating the liberated iodine with thiosulfate. The presence of -C-O-O-C- groupings was confirmed by infrared spectrometry at a wave length of 11.6 microns.

Solid and oil deposits were analyzed for total nitrogen using an accepted Kjeldahl procedure. Infrared examination indicated the nitrogen to be present in the structural form -O-N=O at 5.7 and 8.2 microns. Attempts to analyze inert gas for oxides of nitrogen by mass spectrometry were unsuccessful, but values in the order of 40 ppm. were obtained using a different type of tester which proved to be quite accurate on synthetic blends.

Producing the Blanketing Gas. The "inert gas," used for blanketing purposes, is produced by burning oxygen out of air by an excess of fuel (generally fuel gas) in a sealed combustion unit. Inert gas generally contains some unreacted oxygen, on occasion it has been as high as 1.8 percent, plus traces of nitrogen oxides which are produced in the hot combustion zone at the burner. Given sufficient time and satisfactory temperature conditions, butadiene reacts with oxygen to form butadiene peroxide as described by Alexander,[1] and with nitrogen oxides to form a butadiene/nitrogen oxide complex or vapor phase gum.[3,4]

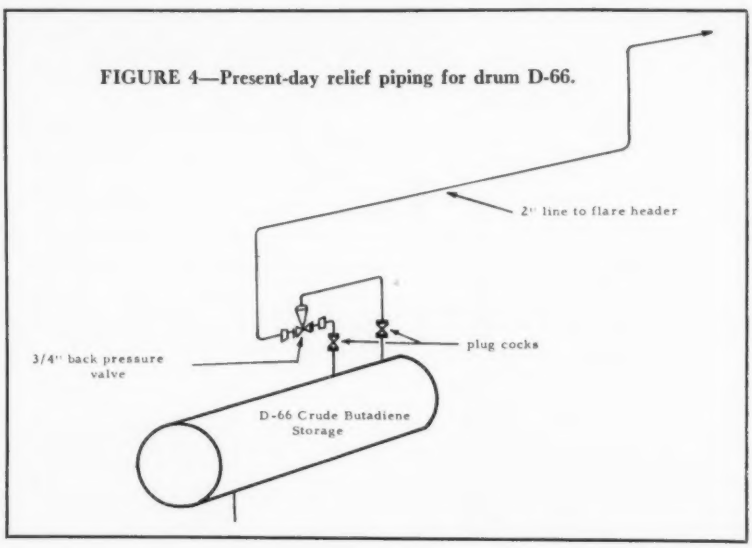
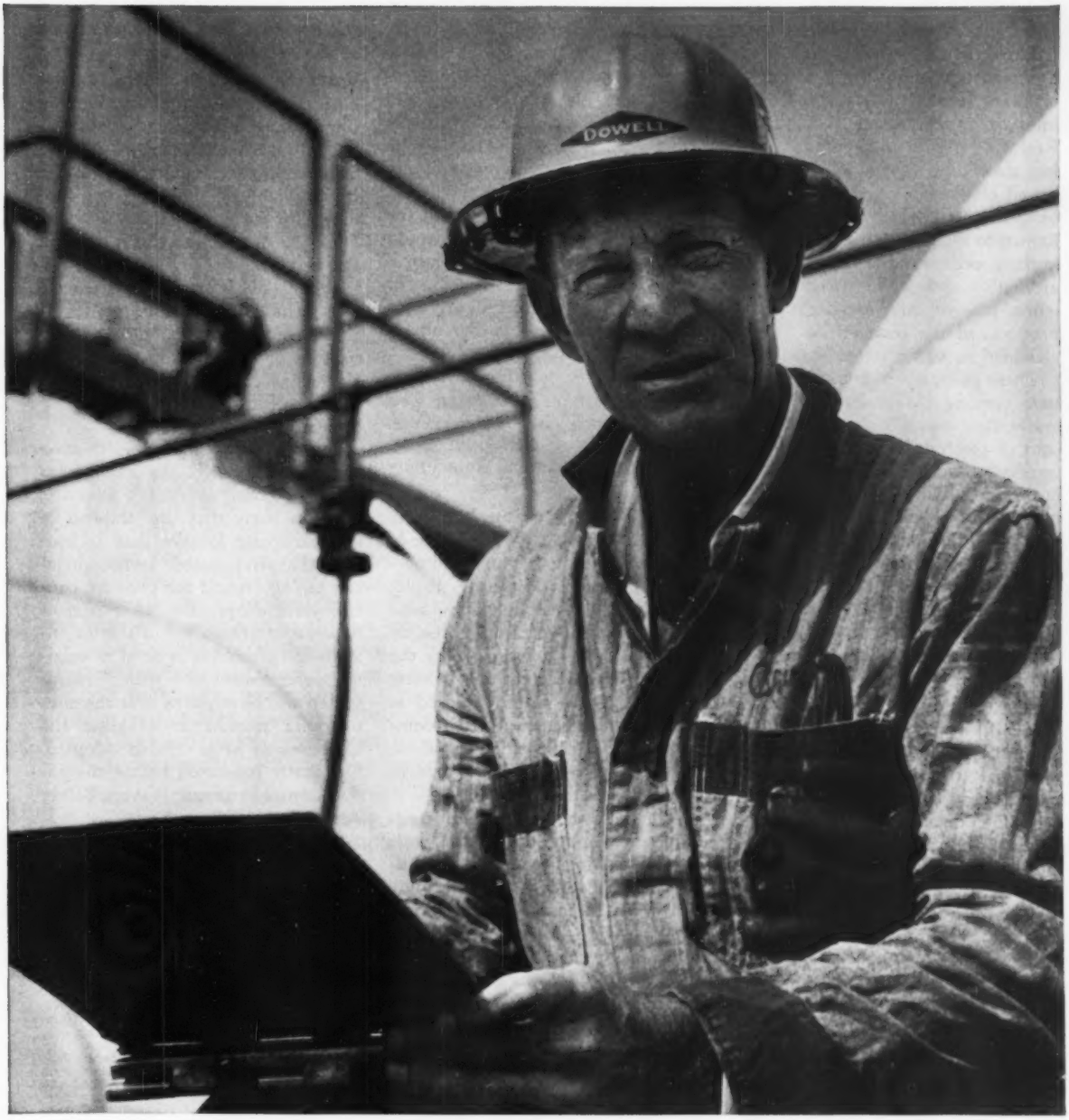


FIGURE 4—Present-day relief piping for drum D-66.



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Put this ability and experience to work for you. Let the Dowell man engineer a profitable chemical cleaning program for you. Dowell—the largest, the oldest, the most experienced chemical cleaning service—Tulsa 1, Oklahoma; and 165 stations and offices in major industrial centers.

Chemical cleaning service for all industry DOWELL

DIVISION OF THE DOW CHEMICAL COMPANY

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Butadiene peroxide is a butadiene insoluble material that explodes with a violence roughly comparable to ordinary explosives such as dynamite or trinitrotoluene.[1] Handy & Rothrock[2] found that peroxide is a low molecular weight polymer comprised of alternating butadiene and oxygen units. Oxides of nitrogen are known to react with many classes of organic compounds, particularly aromatics and unsaturates, and when present in "inert gas" the products of the reaction have been classified as vapor phase gums.

These gums are of complex structure varying in constitution. Generally they contain about five percent of combined nitrogen, and are usually strongly acidic and insoluble in ordinary hydrocarbon but soluble in oxygenated solvents. On heating, the gums decompose more or less violently evolving NO, CO, CO_2, amines and small quantities of oil. They are unstable even at room temperature and the rate of decomposition becomes more or less violent at about 350 F.[4]

Earlier Explosion. It was recalled that on July 31, 1945, there was a minor explosion in a blower which was used to circulate inert gas to some alumina dryers. In this instance a gummy deposit was found on some of the carbon rings and in some of the inert gas lines. Although it could not be proved conclusively, we believe this particular incident was the result of the formation of a vapor phase gum.

An unsaturated fuel was used at the time in the generation of the inert gas so it was replaced with a nearly saturated one and later on with natural gas.[3] There has been no particular problem with the inert gas system from that time up to the present incident.

From the analytical evidence shown in Table 1 it seems likely that oxides of nitrogen present in the inert gas reacted with unsaturates (butadiene) in the piping and vapor space above D-66 to form an unstable oily gum that would be expected to contribute substantially to the explosion.

Since both the peroxides and the gum are oily materials, they would very likely accumulate wherever a trapped or horizontal section of equipment was present. Figure 1 indicates several areas in the piping above the drum where such accumulations might be expected. Ample time for reaction of oxygen and nitrogen oxides with butadiene was available since the emptying, filling, and venting operations were intermittent.

Violent Decomposition. It is likely that once the decomposition rate of the accumulated oily gums and peroxides became sufficiently rapid, (possibly initially induced by heat from the sun, a pressure pulse or mechanical shock of some sort) the mixture would become self-heating and the reaction would proceed at an exponentially increasing rate until violent decomposition resulted. Butadiene peroxide will behave in such a fashion by itself.[1]

Although the oxide of nitrogen complex does not decompose with exceptional violence, it is so unstable it could readily serve as an initiator for the decomposition of butadiene peroxide. It is believed that the oxides of nitrogen complex may well have initiated the reaction and that butadiene peroxide probably supplied the destructive power in the piping above drum D-66. The stretched flange bolts and bulges in the piping are typical of the slow explosive force of butadiene peroxides.[1] Also, the odor associated with decomposed peroxide was present in the explosion area for several hours after the blast.

Corrective Action. Inert gas has been eliminated as a blanketing medium above unsaturated hydrocarbon storage in the plant. Also butadiene, isoprene, and styrene storage is completely eliminated from contact with inert gas and/or oxygen. Fuel gas or natural gas is used in this service.

Piping has been modified whereever it has been possible to effect a simplification. An example of this type of change is shown in Figure IV, which represents the piping arrangement now in existence above drum D-66.

Although it is impossible to state with certainty that the changes to D-66 have been completely effective, it seems likely that the problem in this particular location has at least been sharply reduced. Inspection of the piping around the pressure control valve during the latter part of September (three months after installation) found it to be in its original clean condition. Further investigation will be required over the next 6 to 12 months to evaluate the effectiveness of methods adopted. Originally presented before the International Synthetic Rubber Safety Asso., Oct., 1958.

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TABLE 1—Samples From the Explosion Area

Location	CO_2 Mol %	CO Mol %	O_2 Wt. % Free	O_2 Wt. % Combined	Bd Peroxide Wt. %	N_2 Mol % Free	N_2 Mol % Combined	Nitrogen Oxide Butadiene Complex Wt. %	Comments
D-66 liquid	.....	.....	.....	.....	0.0004	.....	nil	.....	NVM = 0.066 wt.%, TBC = 225 ppm, ∝-acetylene = 3800 ppm, HC distribution normal, S = 0.01 wt. %.
D-66 Vapor	12.0	0.6	0.14	.....	.....	80	nil	.....	Total C_4 = 6.2 mol %
Inert gas	12.7	.....	0.5	.....	.....	86	0.003	.....	Nitrogen oxide = 40 ppm
Oil from plug valve	.....	.....	.....	24	64	.....	0.6	4.2	Could not be detonated but burned very violently when heated on a hot plate.
Oil/solid from control valve	.....	.....	.....	15	41	.....	0.4	2.8	S = 0.18 wt. %
Solid deposits	These samples were all taken from the lines in which the explosion occurred. All were very inactive, would not burn, and could not be detonated.								

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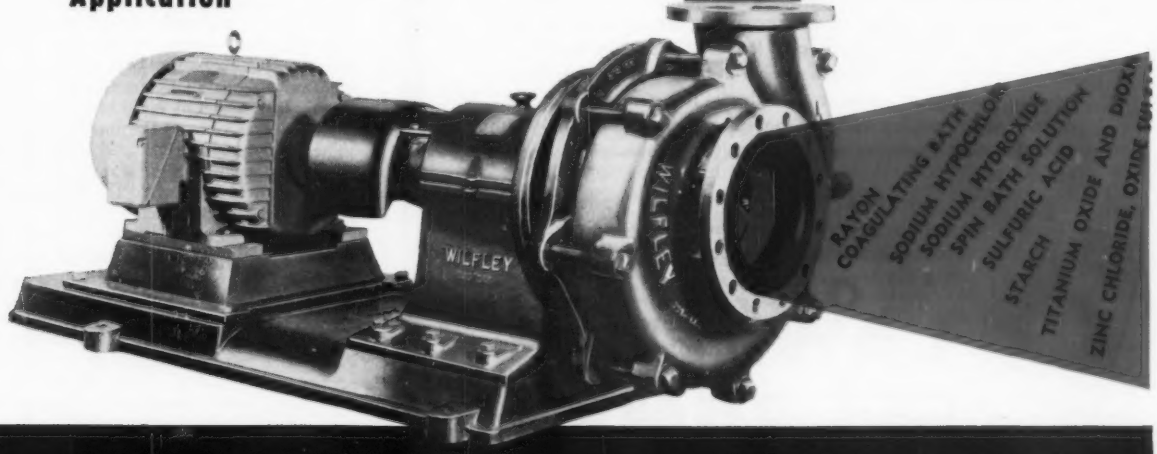

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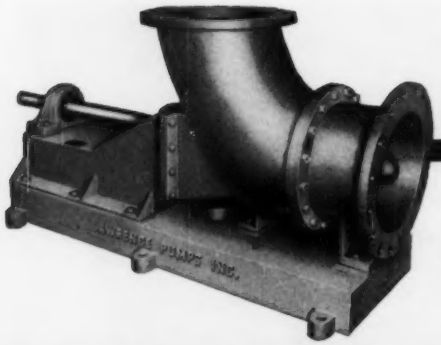
D. S. Alexander is a research and development project leader for Polymer Corp., Ltd., Sarnia, Ont., where he works in light hydrocarbon research and development work. After receiving a M.S. degree from the University of Manitoba, he spent three years in the Imperial Oil Ltd. Inspection laboratories, Sarnia. He joined Polymer in 1943 and held several supervisory positions until 1954, when he moved to the Research and Development division.

Charles M. Finigan is a senior chemist for Polymer Coru., Ltd., Sarnia, Ont., where he works on technical development of hydrocarbon processes. He has 13 years experience in the Laboratory department, Technical division, as a process chemist concerned with the control and chemical development of modified and new light-hydrocarbon processes. Finigan has a B.S. degree and B.A. Honors in chemistry from Acadia University.



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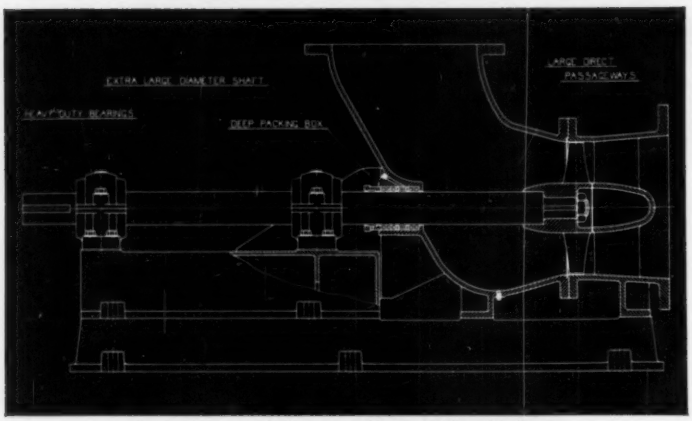

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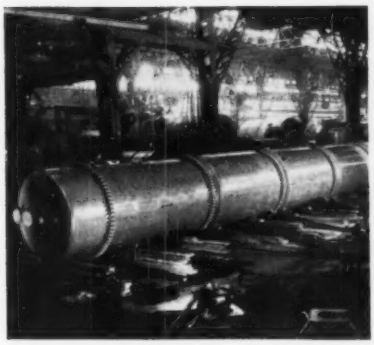

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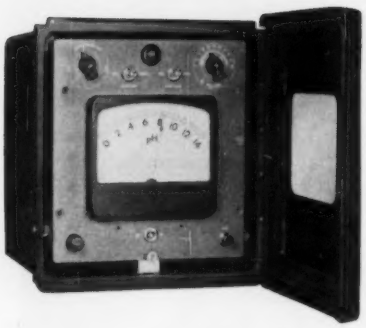

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Table 1
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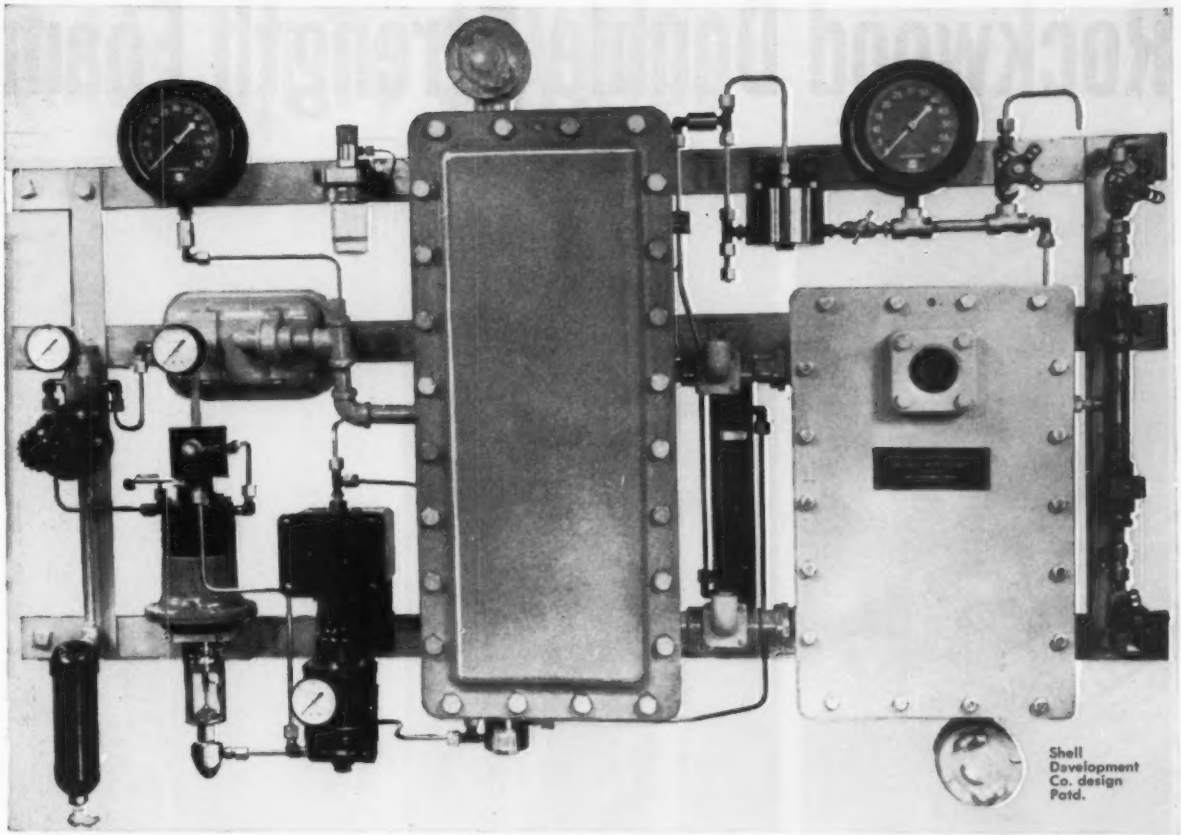
1. In making frank appraisal of employes' work and keeping them informed as to how they are doing
2. Keeping his people well informed of objectives and results of the company and of the department
3. In giving instructions clearly and concisely
4. Training employes in how to do their work
5. Showing he knows and understands the people who work for him
6. Getting all the facts before making decisions
7. Expressing himself well
8. Making decisions promptly
9. Making it easy for employees to ask questions
10. Showing he understands the job he supervises



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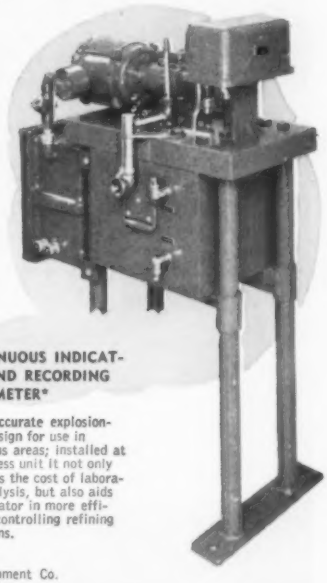

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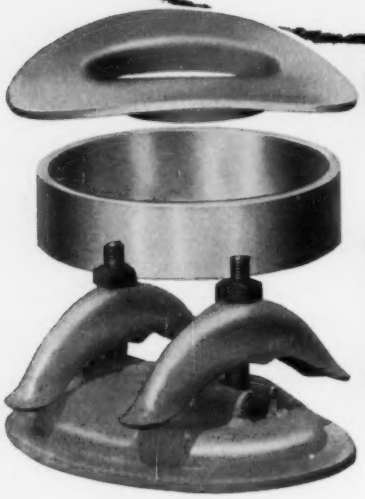

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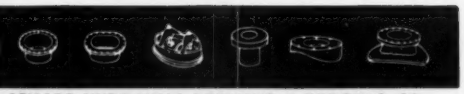

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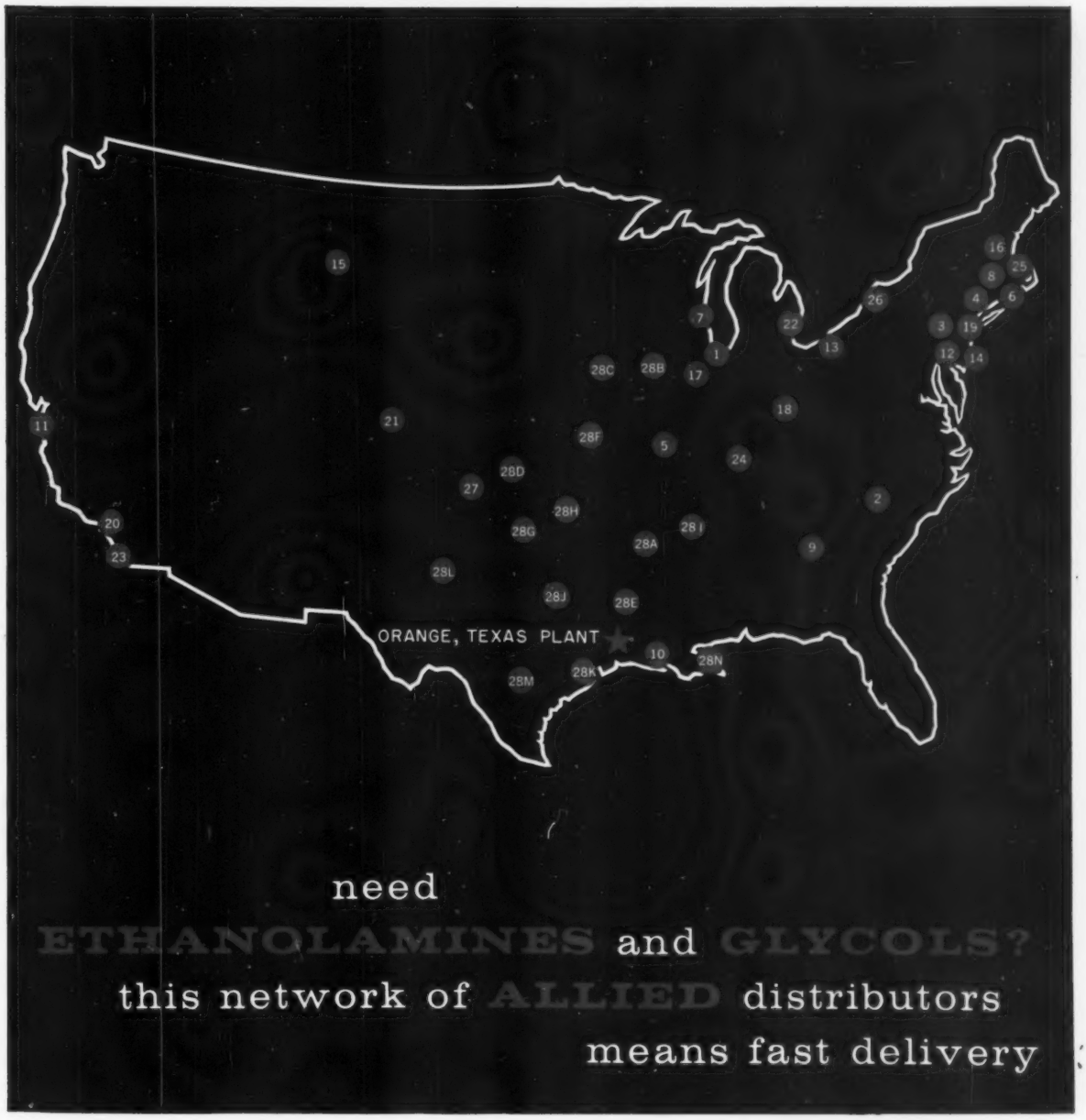

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27. **Southwest Gas Equipment Co.**—Liberal, Kan.
28. **Thompson-Hayward Chemical Co.** (All offices listed below are Thompson-Hayward)

28A—No. Little Rock, Ark. **28B**—Davenport, Ia. **28C**—Des Moines, Ia. **28D**—Wichita, Kan. **28E**—Shreveport, La. **28F**—Kansas City, Mo. **28G**—Oklahoma City, Okla. **28H**—Tulsa, Okla. **28I**—Memphis, Tenn. **28J**—Dallas, Texas. **28K**—Houston, Texas. **28L**—Lubbock, Texas. **28M**—San Antonio, Tex. **28N**—New Orleans, La.

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International Petroleum Exposition
MAY 14-23, 1959
Tulsa, Oklahoma

Allied Chemical

NITROGEN DIVISION
Dept. GA 4-21-1, 40 Rector St., New York 6, N. Y.

Basic to America's Progress

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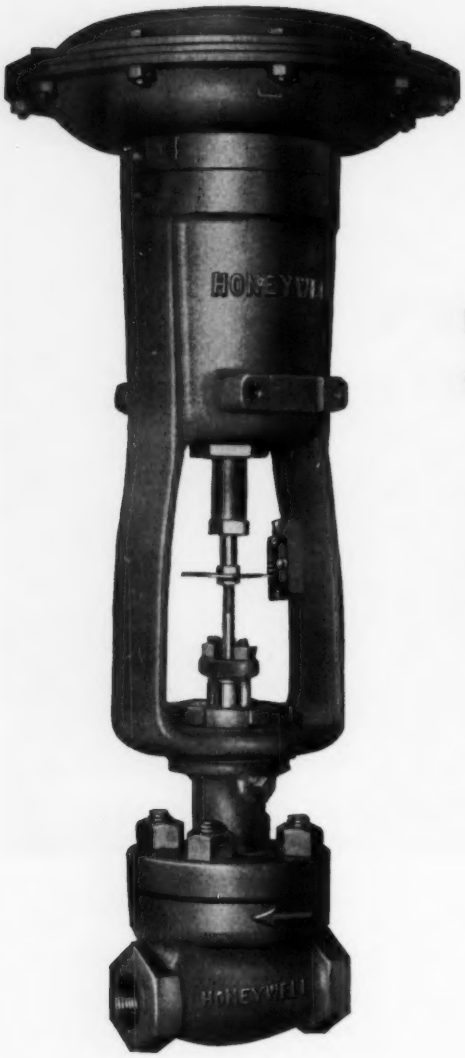
is your PROCESS FLOW SMALL?



Honeywell control valves are available for a wide range of flows

Whether your process flow is a trickle or a torrent, there's a Honeywell automatic control valve to meet your requirements. The Honeywell valve illustrated—Series 800, Type 14 Low Flow—is designed to control small process flows. For each body size, there are interchangeable reduced plug and seat ring combinations . . . with flow coefficients ranging from Cv 0.33 to 8.2. Ultra-low flow plugs are available with Cv's as small as 0.01.

For small or large flows . . . or other process flow conditions . . . Honeywell valves are available in a variety of types and sizes. When you need control valves . . . contact your local Honeywell field engineer. Write for new Catalog C800-1.

MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.

Honeywell

First in Control

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voluntary on the part of the employe to complete it.

The employe is impressed with the idea that no one in the Cities Service organization sees the form after it has been filled out by him. Therefore, there is no opportunity for anyone to know what he says or checks on the form. As a matter of fact we ask the consultant to change the wording on the remarks portion so as to hide identity of an individual.

The supervisor passes out the form to each employe, personally whereever possible, telling him that he hopes he will help by giving his frank opinion in order that he, the supervisor, might improve.

The Payoff. Now you may be asking yourself, "Just what is the payoff in a program of this type of Cities Service, since they do not see the report on the supervisor?" Well, we believe that if you are to get good results through others, you need to know how they feel about you. This being the case, really no one but the supervisor can do anything about this and then he must have a desire to change and improve. Therefore, there is really not any good reason why anyone other than the supervisor should see this report.

There is another payoff to this program, and that is we receive from the consulting firm one composite report on all the supervisors. We usually conduct a series of conferences in each location where we have a concentration of employes and these conferences are composed of from 30 to 60 supervisors. We receive a composite result on such a group.

After receiving the composite reports we compile a report covering all of our supervision throughout the company, which reflects areas in which further supervisory development training is required.

The report received by each supervisor is strictly confidential and what he does with it is up to him. However, we offer to counsel with him after he receives the report, but only if he requests such an interview. The first year about 50 percent of the supervisors requested interviews; about half of these had

CLAYTON MARK

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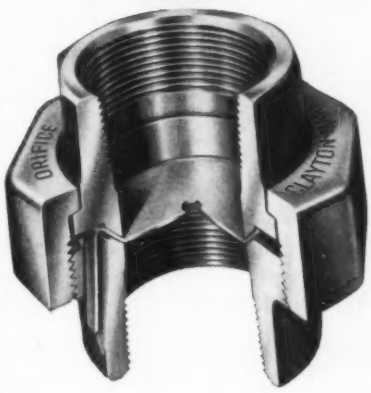
UNIONS

feature for feature are SUPERIOR

BEVELED ORIFICE



Designed to join sections of pipe and at the same time measure or control the flow of liquids and gases under pressure at high or low temperatures, this new BEVELED ORIFICE Union introduced by Clayton Mark finds application in chemical processing plants, oil production facilities, utility power plants, atomic installations and countless other industries.

The union is equipped with a one-piece, stainless steel disc shaped to fit the contour of the seats (ball to cone), thus eliminating the need for gaskets. It is also easy to install on both horizontal and vertical lines.

These carbon steel unions are available in all sizes from ¼" to 2" pipe sizes. Special stainless steel orifice unions can be furnished on special request in 304 or 316 types.

At leading Industrial Distributors in all 49 states.

Specify the brand – Clayton Mark BEVELED ORIFICE

Write today for additional information.

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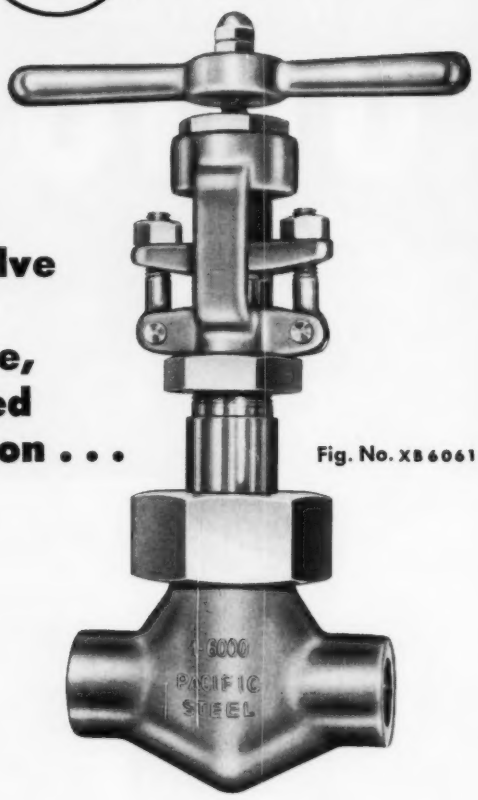
Pacific XB VALVES



THE valve for extreme, repeated operation . . .

Fig. No. XB 6061

New exclusive design features bubble-tight, leak-proof closure everytime . . .

- Absolute sealing regardless of operating variables.
- Small, lightweight.
- Wiping action of one-piece stem and disc unit clears foreign substances from the mating, sealing components.
- Replacement parts can be installed on location.
- Three bonnet designs for ambient and cryogenic service.
- No metal-to-metal contact.
- No galling or seizing.
- All components are bolted or threaded. Elaborate, welded or complicated assemblies have been completely eliminated in the engineered design.
- Inexpensive in first cost — Inexpensive in operation.

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PACIFIC VALVES, INC.
Long Beach, California

very good reports and the other half indicated considerable improvement needed.

In this interview we discuss ways in which they might improve. This year, practically all of our supervisors are discussing their results, and none have lost their enthusiasm in trying to improve. Cities Service will not use these check lists again next year, but will consider them again the following year.

Improvement Started. Table 1 shows the 10 areas where supervisors need the most improvement. Therefore, we have begun to take care of these areas one at a time. From question number one, "Makes frank appraisal of employe's work and keeps them informed on how they are doing?" it is quite obvious that workers are anxious to find out how they are doing on their jobs. In other words, they want to know the same thing as the supervisor asked of them—how they appear to their boss. Therefore, this was the first area we worked on.

The question appearing in the number two position, "Keeps his people well informed of objectives and results of the company and of the department?" clearly indicated a need for better communications. As a result we are now holding communications conferences with all of our supervisors, discussing the various phases of communications—the written word, the spoken word, how we communicate, what we are to communicate as well as case studies and role playing communications.

From the Top Down. We have been quite pleased with the enthusiasm that has been evidenced in this check list program by both supervisors and employes. One factor we feel was very important in the acceptance of this program was the fact that we started with the president and the Board of the company, then worked our way down through the ranks of supervision and management to the frontline supervisor.

As mentioned earlier we have begun to try and take care of the first two items in Table 1 and it is

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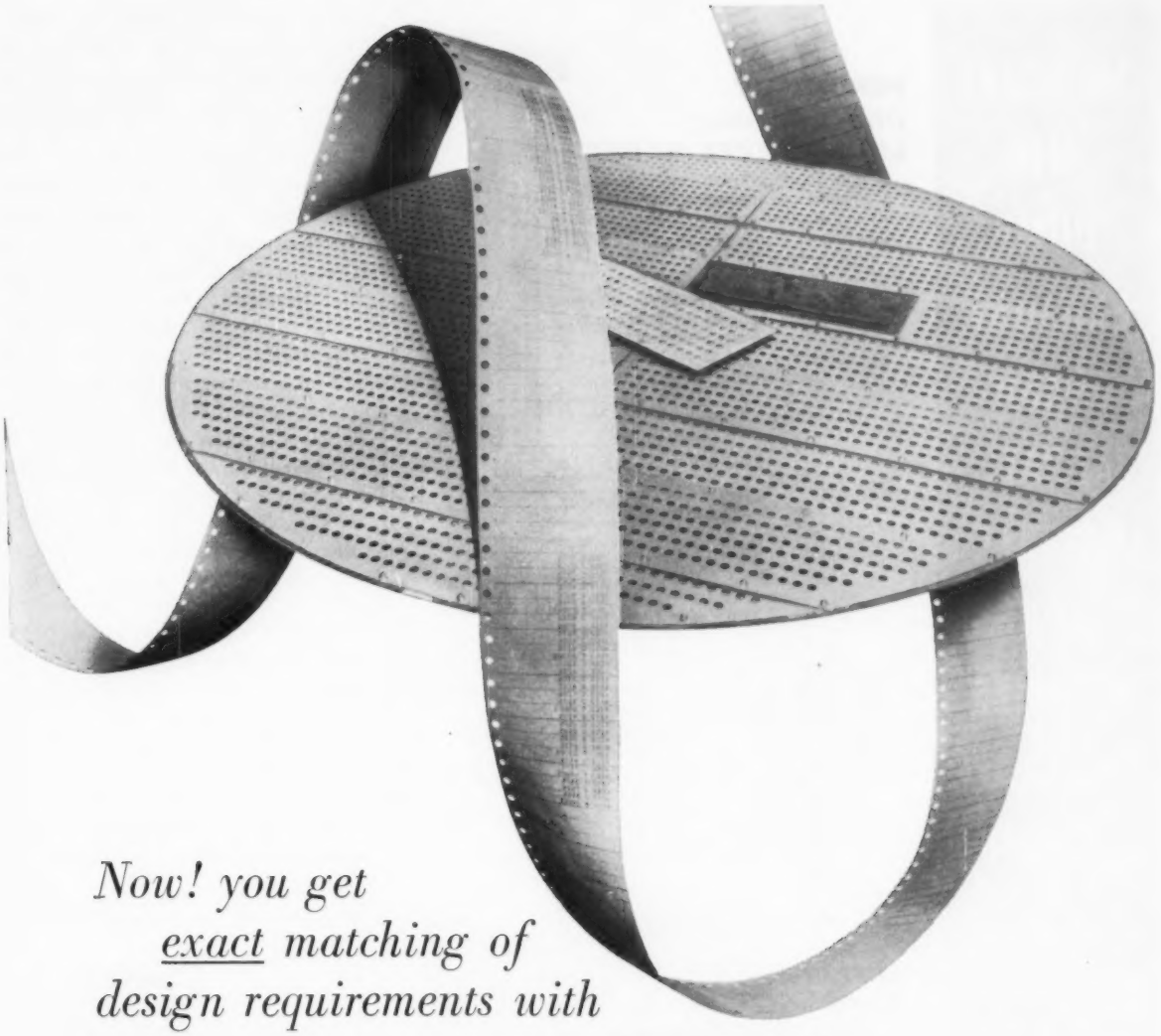

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- Smaller column diameter for a given process capacity.
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- Simpler tray construction.
- Easy maintenance.
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Available in all types of commercially rolled metals. Stainless steel or other corrosion-resistant metals are recommended for corrosive services. As a result, you can now cut replacement costs and production losses caused by downtime, change-overs or cleaning – just by working with Hendrick engineers.

HENDRICK MANUFACTURING COMPANY

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Hendrick is licensed to manufacture ESSO "Jet-Trays," SOCONY "Uniflux," SHELL "Turbo-Grid" and STONE and WEBSTER "Ripple" Trays. Hendrick is also equipped to supply all types of trays to specifications.

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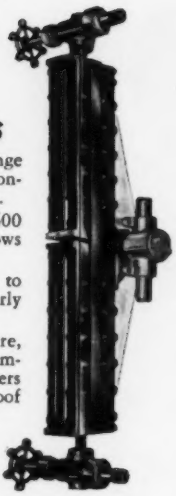

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Designed with exclusive features for range of pressures, temperatures, corrosive conditions or other specific requirements.

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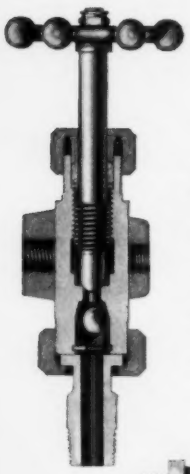
- **SPECIAL SERVICE** — High pressure, Frost-Proof, Heating Tube and Chamber, Welding Pad, Large Chambers and Inclined Gages, Explosion-Proof Illuminator.



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Hydraulic, air and steam operated Penberthy ejectors (jet pumps, eductors, exhausters and syphons) simplify handling of fluids, vapors, gases and "hot" materials. In a variety of standard and special designs and materials.

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Automatic, electric, explosion-proof, submersible and standard types in 8 models, 20 sizes.

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There's Certain Satisfaction in **PRODUCTS BY** PENBERTHY

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- LIQUID LEVEL GAGES
- GAGE VALVES
- SUMP PUMPS

our intention to assist our supervisors in improving on the others as time permits. We realize, however, that the broadside approach will not suffice, therein lies our reason for personal counseling with each individual. However, as you might expect, there are superfluous as well as conflicting questions due to the fact that all employes are checking the forms from vice presidents to oil field roustabouts, refinery personnel, and all the various divisions of an oil company throughout our operating areas.

We also found that what might be important to people in West Texas might not be as important to people in Chicago, Canada, or Bartlesville, therefore it is necessary for some of the questions to be superfluous in nature. You may be assured, however, that human relations is important, regardless of the level or location. Therefore we must continue to strive to improve this area to keep up with technical advances made in our industry.

Originally presented before the Western Petroleum Refiners Association meeting, Houston, January 21, 1959. # #

About the Author

Mark D. Poteet is coordinator of management training, Industrial Relations division, Cities Service Oil Co., Bartlesville, Okla. He is a member of the American Society of Training Directors, Kiwanis Club, American Legion, and serves on API's committee, Training Refining and Production divisions. With Cities Service four years in the Purchasing department as buyer before attaining his present position, Poteet was formerly with Ajax Pipe Line Corp. and Cherokee Pipe Line Co. He has studied at several universities.

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Could your gasoline pass the desert storage test?

Two years in "blitz" cans under the extreme temperature of a Southern California desert is a tough test of gasoline inhibitor effectiveness.

Koppers engineers have data compiled on six commercial gasolines meeting military requirements that were given such a test. Quantitative records of Cu dish gum, ASTM gum, ISD gum, peroxide number, and actual precipitates of these gasolines—at five different inhibitor levels with three popular inhibitors—clearly indicate the superiority of DBPC® Antioxidant, Koppers' inhibitor widely used by petroleum refiners.

May we make an appointment to review these test results with you? Please write, on business letterhead, to Koppers Company, Inc., Tar Products Division, Specialty Chemicals Section, Pittsburgh 19, Pa.

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SPECIALTY CHEMICALS

TAR PRODUCTS DIVISION

Domestic Refinery Runs and Crude Oil Production of Some U.S. Companies in 1958

(Data from all available annual reports of U.S. companies with refinery runs and/or crude production above 10,000 barrels daily.)

Company and Rank in Refining	Total Crude Runs To Stills		Net Domestic Crude Oil Production	
	Barrels Daily	Percent of U.S.	Barrels Daily	Percent of Runs to Stills
1. Standard Oil Co. (N.J.) (Carter, Esso Standard, Humble)	749,000	9.85	379,200	50.6
2. Standard Oil Co. (Indiana)	612,319	8.05	249,698	40.8
3. The Texas Company	598,651	7.87	385,867	64.5
4. Socony Mobil Oil Company	540,351	7.11	208,715	38.6
5. Esso Standard Oil Company	496,000	6.52	.....	....
6. Gulf Oil Corporation	485,034	6.38	316,885	65.3
7. Standard Oil Co. of California	483,397	6.36	253,654	52.5
8. Shell Oil Company	463,778	6.10	301,657	65.0
9. Sinclair Oil Corporation	420,621	5.53	130,144	30.9
10. Cities Service Company	251,784	3.31	117,107	46.5
11. Humble Oil & Refining Co.	227,900	3.00	301,400	132.3
12. Phillips Petroleum Company	218,332	2.87	118,561	54.3
13. Tidewater Oil Company	213,493	2.81	79,637	37.3
14. Sun Oil Company	212,132	2.79	94,271	44.4
15. Atlantic Refining Company	194,071	2.55	88,104	45.4
16. Pure Oil Company	164.632	2.16	58,729	35.7
17. Union Oil Co. of California	164,518	2.16	93,088	56.6
18. Continental Oil Company	148,768	1.96	136,547	91.8
19. Ashland Oil & Refining Co.[1]	134,750	1.77	8,128	6.0
20. Standard Oil Company (Ohio)	128,119	1.69	25,844	20.2
21. Richfield Oil Corporation	119,044	1.57	51,591	43.3
22. Sunray Mid-Continent Oil Co.	103,099	1.36	74,300	72.1
23. Skelly Oil Company	48,971	0.64	64,076	130.8
24. Ohio Oil Company	41,425	0.55	90,059	217.4
25. American Petrofina, Inc.	38,241	0.50	9,342	24.4
26. Tennessee Gas Transmission Co. (Bay Pet. Co. Div. at Denver, New Orleans)	31,254	0.41	21,351	68.3
27. Anderson-Prichard Oil Corp.	30,228	0.40	13,001	43.0
28. Delhi-Taylor Oil Corp.	29,439	0.39	5,217	17.7
29. Clark Oil & Refining Corp.	29,170	0.38	.....	....
30. Monsanto Chemical Co. (Lion Oil Co. Div.)	28,473	0.37	19,461	68.3
31. Plymouth Oil Co.	26,696	0.35	11,712	43.9
32. Champlin Oil & Refining Co.	25,124	0.33	13,962	55.6
33. Carter Oil Company	25,100	0.33	77,800	310.0
34. Signal Oil & Gas Co.	18,841	0.25	33,288	176.7
35. Colorado Oil & Gas Corp. (Derby Ref. Co. at Wichita, Kans.)	15,966	0.21	5,332	33.4
36. South Penn Oil Co.	9,393	0.12	8,402	89.4
[2]Total 35 Companies	6,779,114	89.13	[3]3,962,206	[3]58.4
Remainder of Industry	826,623	10.87	2,746,936	332.3
Total United States	[4]7,605,737	100.00	6,709,142	88.2

[1] Data for 12 months ended Sept. 30, 1958. [2] Total excludes Standard (N.J), whose affiliates, Carter, Esso Standard, and Humble are included. [3] Includes the 3,466,930 barrels daily net production of above companies and an estimated 495,276 barrels daily of royalty and co-owner oil produced by those companies. Also see Footnote ([2]).
[4] Includes 6,660,052 domestic crude and 945,685 foreign crude.

35 Firms Account for Most Crude Runs to Stills

Competition assures reasonable prices for petroleum products. Crude is obtained from companies' own domestic properties, independent producers, and foreign fields. Standard of New Jersey is largest refiner, followed by Indiana Standard, Texaco, and Socony Mobil.

Thirty-five larger companies in 1958 accounted for 89.13 percent of the crude runs to stills at U.S. refineries. They processed 6,779,114 barrels per day out of a U.S. total of 7,605,737 daily.

The 35 companies included all of the so-called major companies and some smaller integrated companies, all having refinery runs in excess of 10,000 barrels daily. The 35 companies are shown in the accompanying table, in the order of their runs to stills.

The remainder of U.S. refinery runs, amounting to 826,623 barrels daily, or 10.87 percent of the national total, were accounted for by independent refining companies. A large part of the independent refining was done by about 140 companies with crude capacities ranging generally from 500 to 10,000 barrels daily, although some was accounted for by plants with runs of less than 500 barrels per day.

As there are well over 200 companies engaged in petroleum refining in the United States, keen competition and reasonable prices for petroleum products are assured.

The greatest share of the country's refining accounted for by one company in 1958 was that of 9.85 percent indicated for Standard Oil Company (New Jersey). Its three U.S. affiliates, Carter Oil Company, Esso Standard Oil Company, and Humble Oil & Refining Company together ran to still 749,000 barrels of crude per day. In numerous other large U.S. industries a large part of the business is accounted for by a small number of companies, and single companies often do well over 10 percent the business in their industries.

Standard Oil Company (Indiana)

With WARREN the Accent is on SERVICE

Warren's DESIRE to serve backed by Warren's ABILITY *(tremendous Resources of Production, Transportation and Storage)* plus Warren's EXPERIENCE as a specialist in its field, gives you . . .

Dependable DELIVERIES OF

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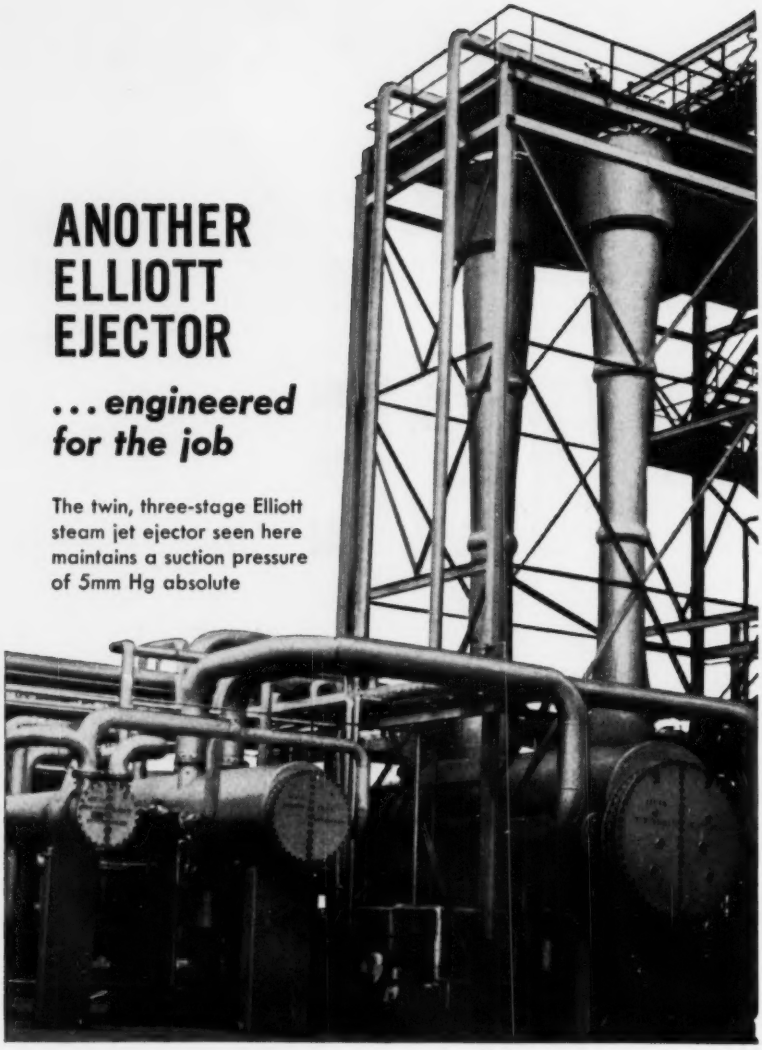

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The twin, three-stage Elliott steam jet ejector seen here maintains a suction pressure of 5mm Hg absolute

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This unique, giant-sized ejector is the largest vacuum installation ever built. The design problem here was to engineer a unit which would efficiently and economically maintain the specific suction pressure required by the application. To accomplish this, Elliott engineers designed a twin-type ejector with two vertical first-stages which are 40 ft long, have 60-inch diameter inlets, and discharge to a 20,000-sq ft intercondenser. The two 20-inch second-stage ejectors discharge to a 6000-sq ft intercondenser and the third-stage ejectors discharge to a 3000-sq ft aftercondenser.

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Available literature on single-stage, multistage and corrosion-resisting types illustrate Elliott's versatility in ejector design and construction for all sorts of chemical and industrial process applications. Contact your nearby Elliott District Office or write Elliott Company, Jeannette, Pa.

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GB-2

Happenings . . .

was the second largest U.S. refiner in 1958, with runs of 612,319 barrels daily or 8.05 percent of the U.S. total. The Texas Company ranked third, having processed 598,651 barrels of crude per day, or 7.87 percent of the national total. Socony Mobil Oil Company was fourth, with runs of 540,351 daily (7.11 percent). Esso Standard by itself ranked fifth, in processing 496,000 barrels daily.

Four other companies had runs above 400,000 barrels daily, including Gulf Oil Corporation, Standard Oil Company of California, Shell Oil Company, and Sinclair Oil Corporation.

The next five largest refining companies had refinery runs between 200,000 and 252,000 barrels daily. They were Cities Service Company, Humble Oil & Refining Company, Phillips Petroleum Company, Tidewater Oil Company, and Sun Oil Company.

Refinery runs ranging from 150,000 to 200,000 barrels daily were reported by Atlantic Refining Company, Pure Oil Company, and Union Oil Company of California. Runs of 100,000 to 150,000 daily were made by Continental Oil Company, Ashland Oil & Refining Company, Standard Oil Company (Ohio), Richfield Oil Corporation, and Sunray Mid-Continent Oil Company.

The above companies with refinery runs exceeding 100,000 barrels per day numbered 20, by excluding Jersey's affiliates, Esso Standard and Humble. The 20 companies together had runs of 6,405,893 barrels daily, or 84.22 percent of the U.S. total.

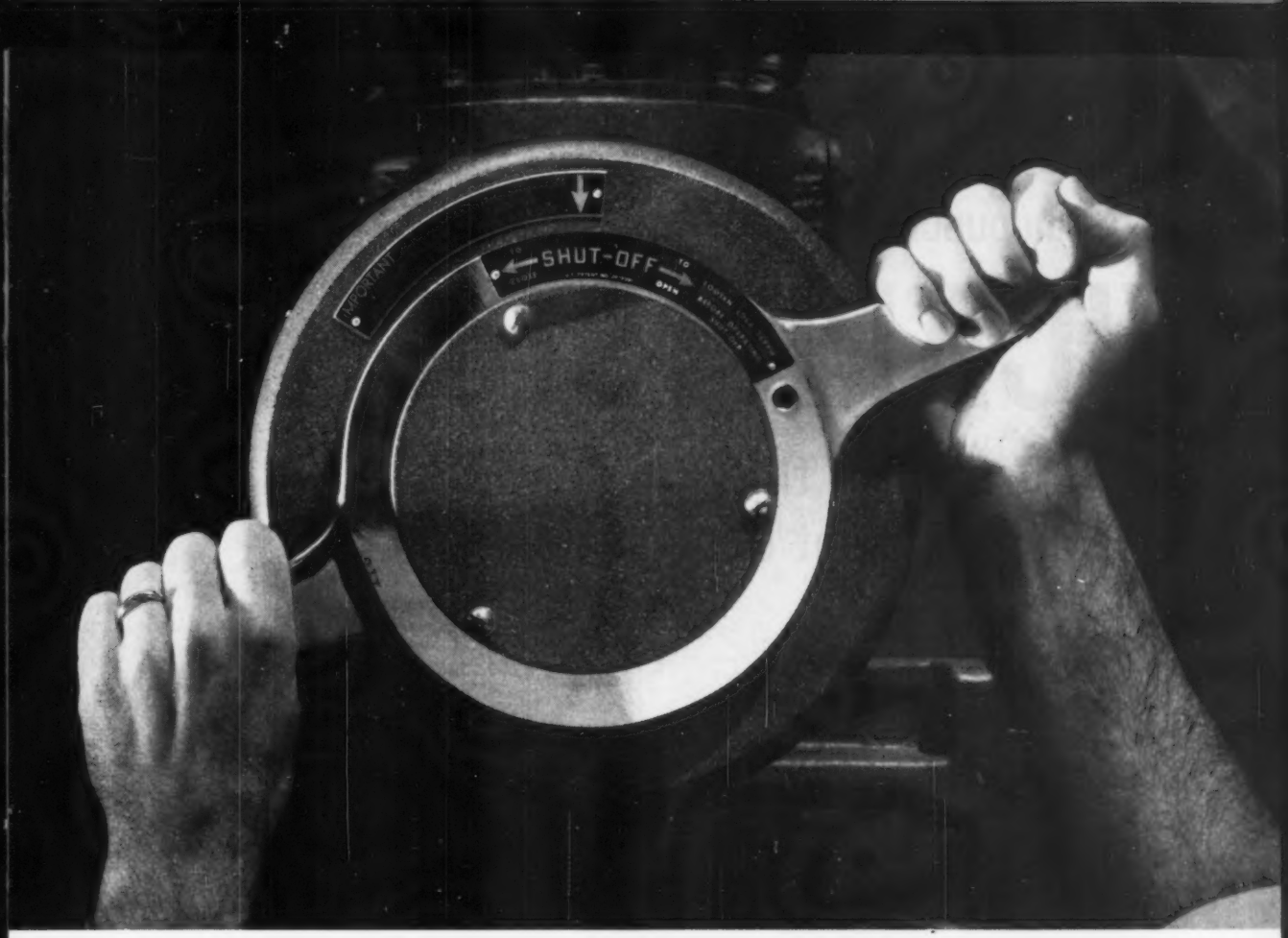
Each of the remaining 14 companies shown in the table herewith ran to stills less than 50,000 barrels of crude per day in 1958.

Of the total U.S. refinery runs of 7,605,737 barrels of crude oil daily in 1958, 12.4 percent (945,685 barrels daily) was foreign crude and 87.6 percent (6,660,052 barrels daily) was domestic crude. While major companies were the principal crude importers, some foreign crude was used by independent refiners, especially some with coastal plants. The amount of domestic crude run to stills in 1958 was approximately the same as the total domestic crude production of 6,709,142 barrels daily.

The 35 companies that refined 89 percent of the crude in 1958 (6,779,114 barrels daily) met 58.4 percent of their requirements (3,962,206 barrels daily) from their own domestic producing properties, counting their own net production and the usual one-eighth of production purchased from the royalty owners.

Along with the numerous independent refiners, the 35 larger companies had access to an additional 2,746,936 barrels daily of domestic crude produced by independent operators. That independently produced crude was equivalent to 36.1 percent of total refinery requirements. The balance of about 900,000 barrels of crude processed daily was supplied by imports.

For more data on advertised products, use Readers' Service Cards, last page.



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No need to find another place to put a tankful of liquid in a hurry. No big wrenches. No sweat or strain.

When the job's done, a few turns put the mixer shaft back in operating position again, ready for business—*automatically* realigned.

It's *easy*—and it saves money.

You'll see these handles in refineries and at pipeline terminals all over the country. They're visible proof of the long-term savings refinery men look for, and find, in this side-entering mixer.

Just as important are some of the economies that *don't* show on the outside.

The wide choice of stuffing boxes, for instance: there's one to meet every mixing or blending condition.

The rotary mechanical seal that takes the place of a stuffing box, if you wish. It eliminates all repacking, positively stops leakage—and is *easy to replace* when it finally wears out.

There are many other savings you'll want to know about before you decide on mixers for *your* big tanks. Your LIGHTNIN Mixer representative can tell you what they are. You'll find his name listed in Refinery Catalog. Why not get in touch with him now?

BLENDING PRODUCT or controlling BS&W in crude—you get the job done faster, at lower cost with LIGHTNIN Mixers. They're used in tanks as big as 200,000 barrels. Results are guaranteed.

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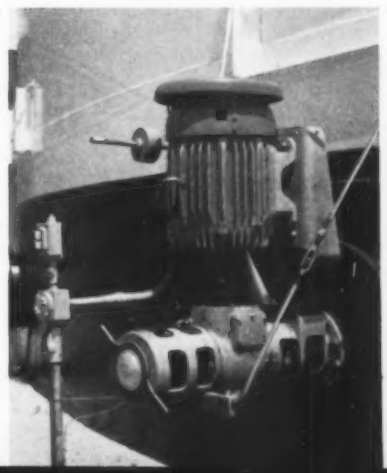

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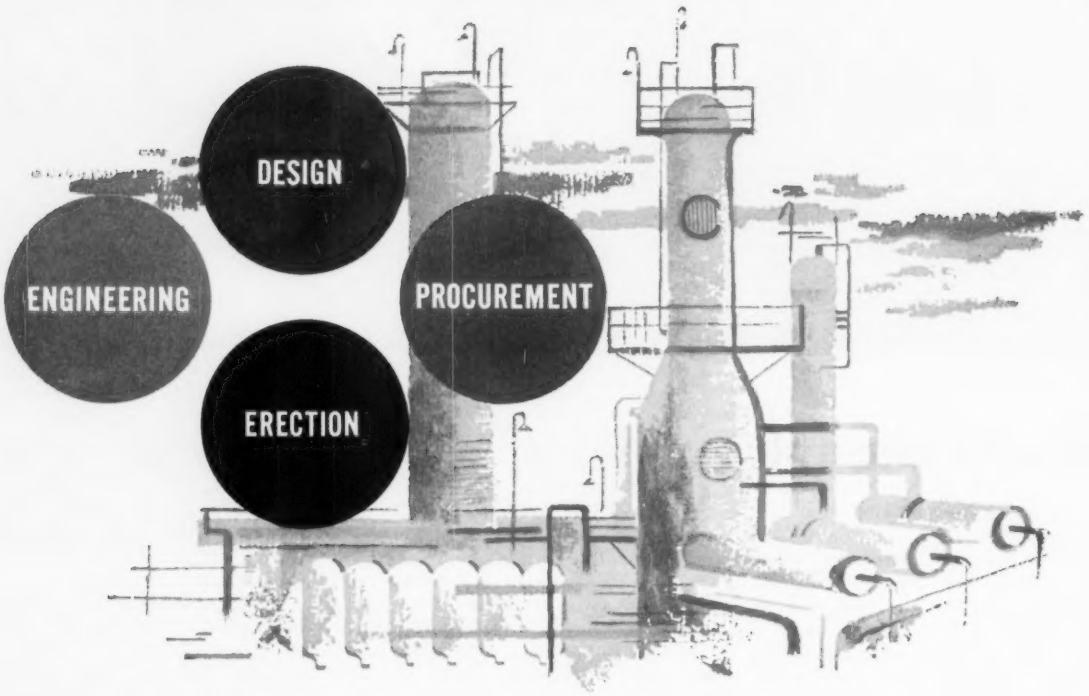
to serve in the industrial development of Venezuela



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Headquartered in Caracas, this new company combines the sound Venezuelan construction and business experience of Shevica S.A. with the world-wide technical and engineering "know-how" of Procon. As a first step in its service to Venezuelan industry VICAPROCON is now engaged in studies for various projects relating to the oil and chemical industries.

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WOGA Asks for Study of Pollution Rule

A joint day-by-day study by fuel users and the Air Pollution Control District of the effect of Rule 62, which will ban fuel oil use during the summer months, has been recommended by Western Oil and Gas Association.

"We suggest that a panel be formed of your scientists, our own, and other interested parties to establish criteria for evaluation of the rule," Felix Chappellet, WOGA vice president and general manager, said in a letter to S. Smith Griswold, air pollution control officer. Chappellet pointed out that it was the industry's hope that "in this way, the effect of Rule 62 can be explored so as to see whether it is a successful or an unsuccessful experiment, or an experiment simply requiring revision."

Rule 62, passed last November by the Board of Supervisors, provides that fuel oil in excess of 0.5 percent sulfur may not be burned in the Los Angeles basin from May 1 to September 30, 1959, and from May 1 to October 31 in succeeding years.

Facts concerning air pollution as presented by scientific and control agencies, rather than those of "non-experts", should be relied upon by Los Angeles City Council members, says a spokesman for the Western Oil and Gas Association. Kenneth E. Kingman, chairman of the Air Pollution Control committee of WOGA, told council members that Air Pollution Control District figures show refineries emit only five percent of the total hydrocarbons into the atmosphere while automobile exhausts account for 75 percent, despite claims to the contrary.

The WOGA spokesman made his statements in refuting theories made by Chandler Phillips. "Phillips say that we have smog because today's refineries emit more sulfur than they did previously, but APCD figures show this is definitely not true," Kingman declared. "There is less sulfur dioxide in the air today than there was ten years ago and the oil industry itself has cut its loss of sulfur dioxide by two-thirds according to figures produced by APCD studies," Kingman added.

Kingman produced charts, using APCD figures, showing total amounts of pollutants emitted to the air. The charts compared pollutants from catalytic cracking plants as opposed to pollutants from other sources. Catalytic crackers emitted 20 tons of hydrocarbons into the atmosphere, according to APCD figures, compared with 1,434 tons from all other sources. Other figures showed 43 tons of sulfur dioxide produced by the catalytic crackers as opposed to 503 tons from other sources, and five tons of oxides of nitrogen compared with 428 tons from other sources.

Kingman told council members that Phillips' accusations that the use of more lead in gasoline causes smog is a fallacy. Figures of the U. S. Bureau of Mines indicate there have been slight fluctuations from year to year in lead in gasoline, Kingman pointed out, but there has been no increase. A chart Kingman showed council members noted that the maximum allowable concentration of lead introduced into the atmosphere was 200 micrograms per cubic meter. Refineries produced only 3.6 micrograms compared to the 200 maximum limit.

"Over the last ten years there has been a vast amount of research and a lot of work on the smog subject," Kingman told the council. "If there is one thing that has been clearly demonstrated it is that smog is not a simple problem. It does not help the solution to go about spreading confusion through misinformation."

Kingman invited an inspection of the refineries by council members at any time. "Our only desire is that we be judged by the truth and by the facts, not by prejudice or superstition," said Kingman.

IPAA Forecasts Crude Market Increase

An increase of nearly 800,000 barrels daily in the market for domestic crude oil for the next three months, May-July, over the same period last year has been forecast by IPAA. In its monthly Supply and Demand Outlook the Association stated the market for domestic crude would be about 7.2 million bpd through July compared with 6.4 million bpd during the same period last year.

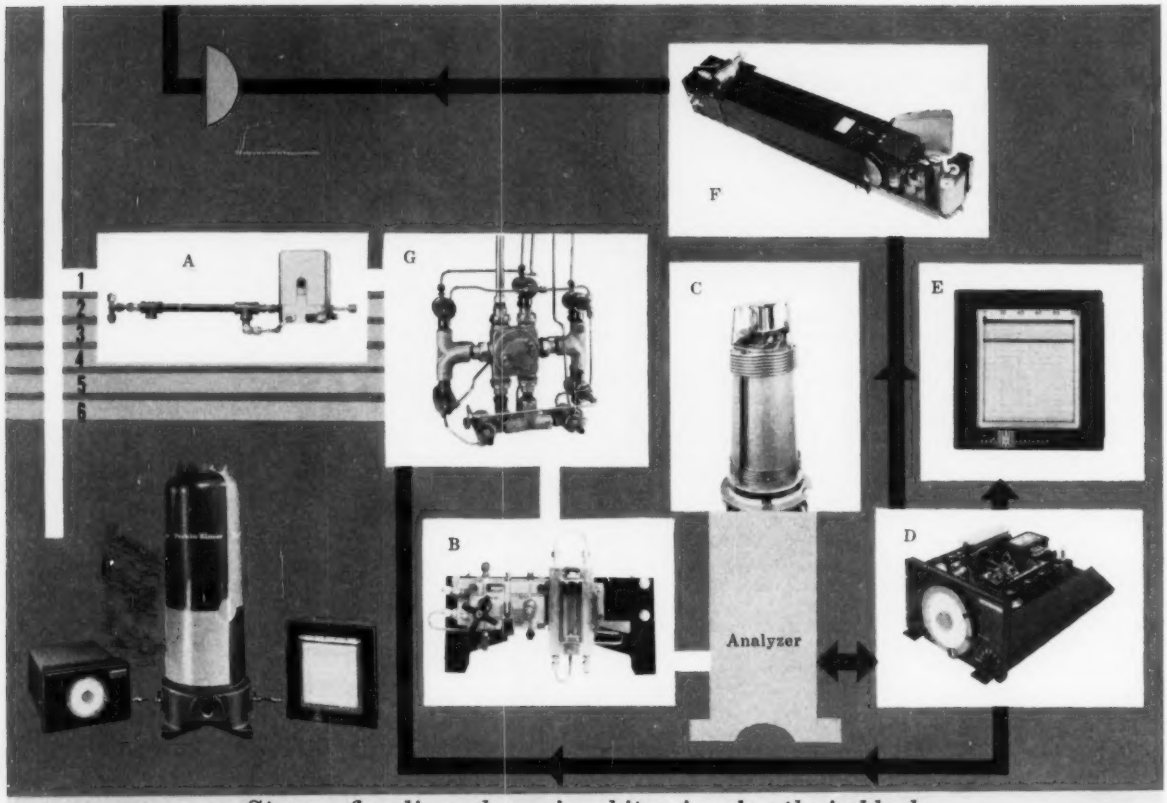
The significance of this increase was emphasized by the Association's forecast of a seasonal decline in total domestic

what does

$$\triangle F/A = \triangle p$$

mean to you?

(Continued on next page)



Stream flow lines shown in white, signal paths in black

This block diagram shows how six process streams can be selectively analyzed by the P-E Model 184-B. For brevity, Stream #1 only will be followed through the system.

Stream #1 is tapped, and the sample vaporized in the Liquid Sample Vaporizer (A). Sample #1 then flows (with the other five vaporized samples) into the enclosed, heated Multi-Stream Solenoid Switching Manifold (G). The solenoids are electrically directed by the Programmer (D). As it is selected, Sample #1 is valved into the Final Sampling Assembly (B), where it is filtered and metered into the Analyzer. The Analyzer quantitatively and qualitatively separates the sample's components by gas chromatography, produces signals which appear as a bar graph on Recorder (E).

The signal can also be fed into a Pneumatic Control Accessory (F) which produces a 15 psi signal for automatic control of one variable component of the stream.

The Analyzer with Reverse Flow Valve (C) allows for the analysis of light components individually plus a "total heavies" measurement; it back-flushes and analyzes heavy ends as a single peak, shortening analysis time in the process. The Programmer (D) is available in a variety of modes for multi-component and multi-stream analysis. It controls the Switching Manifold (G) and the Analyzer, and the read-out of the Recorder (E).

All flow lines and sampling building blocks are kept above the dew point, where necessary, by steam tracing.

UNTIL NOW—PROCESS CONTROL INSTRUMENTATION LIKE THIS HAD TO BE CUSTOM-BUILT

Standard building blocks give the new P-E Model 184-B Process Vapor Fractometer the flexibility of the most advanced special engineering developments in process gas chromatography.

A new, highly versatile instrument, the Model 184-B brings automatic process control by gas chromatography within the reach of virtually any petroleum or chemical processing plant.

The Model 184-B uses *building block* sampling and sensing units in various combinations to produce process analytical systems which mean continuing extra dividends through reduced maintenance, low-cost training and highest reliability.

These standard building blocks include multi-port sampling valves for backflushing and analyzing heavy ends . . . versatile multi-column systems . . . multi-stream programmer kits . . . pneumatic units for automatic control . . . and a wide variety of sampling devices.

Perkin-Elmer, the world's largest manufacturer of gas chromatographic instruments, will help you in your process instrumentation requirements. For more information, write for a new descriptive booklet.

All building blocks in any P-E system conform to standard refinery and chemical plant safety practices.

INSTRUMENT DIVISION

Perkin-Elmer *Corporation*

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and export demand of more than 1.5 million bpd for the next three months, averaging 9 million bpd. However, the IPAA stated, this demand of 9 million bpd would be an increase of five percent over the same period in 1958.

Total domestic and export demand during the first quarter of this year averaged 10,690,000 bpd, the Association said. This was 739,000 bpd, or 7.4 percent higher than for the first quarter of last year. IPAA cited an increase of 291,000 bpd in demand for gasoline and an increase of 232,000 bpd in demand for residual fuel oil during the first quarter.

The government's new mandatory oil import program took on new emphasis in light of a total crude and refined product imports level of 2.1 million bpd for the first quarter of this year. During the next three months, the Association stated, imports are expected to average about 1.45 million bpd, down 140,000 bpd from the same months last year, but considerably below the first quarter 1959 level. Although crude oil imports were about 950,000 bpd during the first three months of this year, imports of refined products established an all-time record of about 1,175,000 bpd, an increase of 63 percent over the first quarter of 1958.

Petroleum inventories at the end of March, the Association said, totalled 745 million barrels, a decline of 22 million barrels from the year-ago level.

Blaw-Knox Wins National Safety Award

The First Place National Safety Award for 1958, given by the National Constructors Association, has gone to Blaw-Knox Chemical Plants division. The award, for the 12 months ending September 30, 1958, is in recognition of the division's good safety record for the year. The winning performance was a frequency rate of 1.90, and a severity rate of 28.57, both based on the per-million manhours worked. The division had only four lost-time accidents during the year for a total of 60 man days lost time.

Esso Forms Rocket Fuel Research Group

A new unit of scientists has been organized by Esso Research and Engineering Co. to conduct advanced research on super rocket fuels under a contract awarded by Army Ordnance. The $1.3-million one-year contract is on a cost, non-profit basis and provides for development of improved solid propellants.

Dr. John P. Longwell will direct the project and Dr. John F. Kolfenbach will be assistant project head.

The company's experiments will involve both petroleum-based and non-petroleum materials. Its goal was stated by Roy W. Johnson, ARPA director, who said: "We are looking for even more energetic solids to vastly increase our present capability. The achievement of breakthroughs in the solid propellant field will have important bearing on many critical programs which directly affect the deterrent capability and national security posture of this nation."

FAA Discounts Asphalt for Airport Use

Asphalt has been discounted for use on runways, taxiways and holding pads at Washington's International Airport by the Federal Aviation Agency which has given an affirmative nod to Portland cement. The airport is being constructed at Chantilly, Va., 25 miles from Washington, D. C. Reason given for the decision—Portland cement has minimum acceptance life of 25 years, resistance to jet blast and fuel spillage, elimination of rutting, prevention of "shoving" as a result of high-speed turns, light reflective quality, skid resistance and nominal upkeep. FAA reported that consulting engineers found cement "superior in every respect except first cost." The Asphalt Institute claims it could do the job for $3 million less than the $9.1 million required for concrete. But consultants said these estimates were based on asphalt design they considered unacceptable, and that this accounts for a large part of the savings claimed by asphalt.

Three Firms to Unite For Urea Process

Three companies representing three stages in the life of a chemical—process development, plant engineering, construction, and production have entered a novel arrangement for

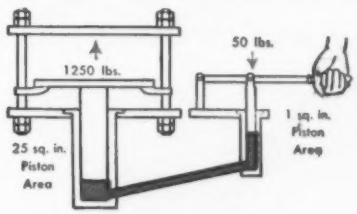
(Continued from preceding page)

$$\Delta F/A = \Delta p$$

. . . is the mathematical expression for Pascal's Principle which states that: "pressure applied to a confined fluid is transmitted uniformly to all areas of the confining fluid."

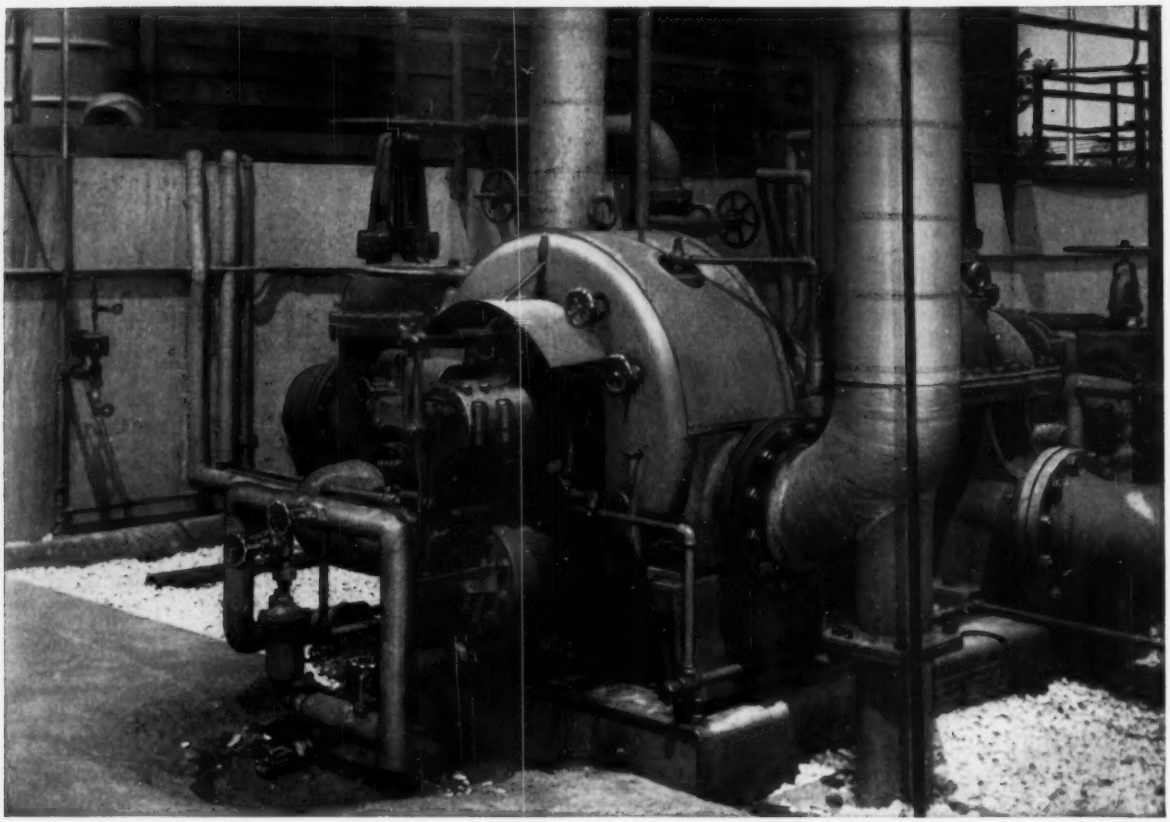
In the drawing below, notice how a relatively small pressure of 50 pounds applied to the 1 sq. in. piston raised 1,250 pounds on the 25 sq. in. cylinder. Pascal discovered how to multiply the muscles of man a thousand fold! Today, the light touch of a woman's toe against a foot pedal smoothly yet quickly slows and halts a two ton automobile.

Pascal's Principle had been known for hundreds of years when a man by the name of Sven Nordstrom successfully applied the principle to



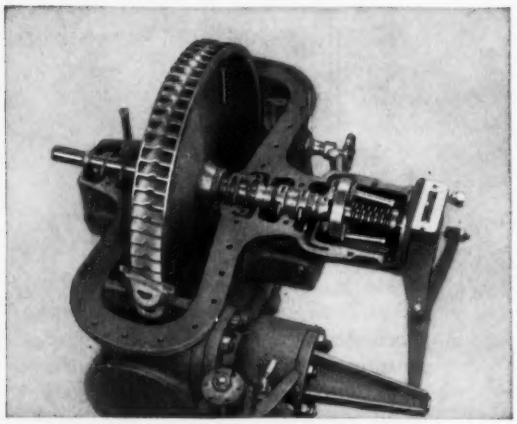
Here is a demonstration of Pascal's Law. A given pressure of 50 lb lifts 1250 lb over an enlarged area of 50 to 1 ratio

create a most unusual innovation in valves—his invention, the lubricated plug valve. In the most elementary terms, this valve is simply an old fashioned plug cock (used since the days of Pompeii) to which Nordstrom ingeniously applied the Principles of Pascal.



TERRY SOLID-WHEEL TURBINES

used exclusively at Baton Rouge plant of W.R.Grace & Co.



The upper photograph shows one of the 17 Terry turbines installed at the Baton Rouge, La., GREX high-density polyethylene plant of W. R. Grace & Co. Above, a typical Terry solid-wheel turbine with cover removed to show the wheel construction.

In purchasing equipment for their new 50,000,000-pound high-density polyethylene plant, W. R. Grace & Co. standardized, wherever possible, on a single source of supply for each type of equipment used. Consistent with this policy, Terry steam turbines were used exclusively throughout the utility and process sections of the plant.

A total of 17 turbines were placed in service for driving pumps and fans. These are all of the solid-wheel type, ranging in capacity from 50 to 240 HP.

Terry solid-wheel turbines are known for their long life and sure dependability under the most-trying operating conditions. They feature a single-piece wheel which is virtually indestructible.

Send for details of these trouble-free turbines. Ask for a copy of bulletin S-116.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

TERRY

TT-1214

the future sale of a proven process to make urea. Pechiney of France, which pioneered the total recycle process by making urea from ammonia and carbon dioxide using a neutral oil slurry to recycle unconverted raw material, will license its original know-how and rights through Foster Wheeler Corp.

The process will be commercially augmented by joining with operating experience obtained over the past five years by W. R. Grace & Co., one of the first licensees of the Pechiney process in the United States.

Known as the Pechiney-Grace Process, it will incorporate the most recent advances in urea production and quality control developed at Grace Chemical division's Memphis plant.

Dinner Will Highlight API Meeting

The traditional dinner meeting which will be one of the highlights of the 24th midyear meeting of API's Division of Refining, New York, May 27-29, will feature a special program of entertainment.

The program is being developed by B. B. Turner, president of Ethyl Corp., New York; A. P. Frame, Cities Service Co., New York; W. V. Ischie, Sinclair Refining Co., New York, and J. S. Worden, Texaco, Inc., New York. The program is a departure from past customs. Previously, dinner meetings had always featured a prominent leader of business, industry, or education, as speaker.

'Largest' Data Processing Unit Installed

Phillips Petroleum Co. has installed what it says is the largest type of electronic data processing machine in commercial use. Operation of the digital computer by Phillips at Bartlesville started in February.

The company is also making use of the machine's special design to handle both technical and business calculations. The giant computer supplements and greatly extends Phillips electronic computing, which includes work done with several other machines in the company's computing centers at Bartlesville and at Borger, Texas.

API Publishing USSR Petroleum Articles

Abstracts of important Russian petroleum articles are presently being prepared on a current basis, according to the API. Its Central Abstracting Service, an activity of the Division of Refining, now receives 26 basic Russian publications by airmail and covers them promptly in a biweekly bulletin, "API Abstracts of Soviet Petroleum Technology."

This new Russian-abstract bulletin is a supplemental service to API's regular "API Technical Abstracts." Abstracts available elsewhere reportedly run nearly a year behind original Russian publication, and are not oriented to the petroleum industry. In addition, secondary journals do not abstract many items which are important to oil men.

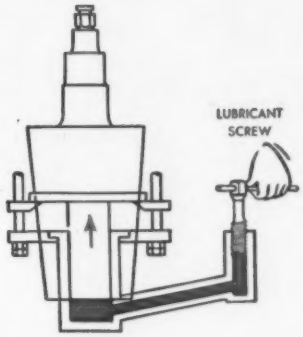
"API Abstracts of Soviet Petroleum Technology" provides coverage of Russian fundamental and technological work in both refining and petrochemicals. The 26 journals selected for abstracting cover a high percentage of the pertinent Russian work. They were chosen by experts in Russian petroleum technology.

Further information about this service may be obtained by writing to W. T. Gunn, Director, Division of Refining, American Petroleum Institute, 50 West 50th Street, New York 20, New York.

Octanes Same as in March, Says Ethyl

Gasoline on sale at service stations in April showed national weighted averages of 99.1 octane number for premium and 91.7 octane number for regular, according to the latest monthly

The perfect application of a principle



The lubricant system in the Rockwell-Nordstrom valve is a closed hydraulic system acting much like the two pistons shown on the facing page. Instead of having a separate piston to "charge" lubricant into the valve, the screwed lubricant fitting at the top of the plug acts as the first piston. When lubricant is forced through the fitting by a pressure gun or if the lubricant screw is manually turned down, hydraulic force is magnified and forces lubricant through the channels in the plug.

The plug then acts in much the same fashion as the second piston. A shot of lubricant from a pressure gun or a few turns of the lubricant fitting minutely unseats the plug upwards against the resilient shoulder seal, freeing the plug for smooth, easy turning.

(Continued on next page)

FINE PRODUCT CONTROL

is easier with a LJUNGSTROM® AIR PREHEATER

—and finer control means a more uniform, more profitable product

Income is up $58,000 a year at one East Coast refinery because Ljungstrom Air Preheater permits finer control and advanced design units. This boosts average product ratings *as much as two octane numbers.*

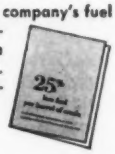
The most modern heat transfer system can be operated at peak efficiency with a Ljungstrom gas-to-gas regenerator. A Ljungstrom can recover as much as 1000°F heat from the exhaust of stills or boilers. Instead of letting this heat escape up the stack, the Ljungstrom returns it to the furnace combustion air.

Hotter combustion air can boost the output of a pipe still, too—by as much as 25%. Or, it can cut your fuel bill by an equal amount—or permit you to use cheaper fuels that were previously considered useless. And whatever fuel you use, there's less slag, fewer deposits, because a Ljungstrom Air Preheater helps burn fuel more completely. Some plants have "written off" the cost of their Ljungstroms *in only nine months.*

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

Here's documented evidence. One company's fuel savings with a Ljungstrom Air Preheater are factually described in a published magazine article by O. F. Campbell. A reprint of this case history is yours free. Simply write:



survey of antiknock quality compiled by Ethyl Corporation. Both averages were unchanged from March but were .6 octane number above a year ago.

Average tetraethyl lead contents in April were 2.52 ml per gallon of premium gasoline and 1.71 ml per gallon of regular gasoline.

For companies marketing more than one grade of premium, the survey showed a range of 100.8 to 102.7 octane number for the highest grade, on the basis of 43 samples in 22 cities.

Thirty-one of the 57 cities in Ethyl's survey reported increases over March in the average octane number of their premium gasolines, one by 1 octane number. Fifteen cities reported decreases while 11 were unchanged. In regular gasoline, 24 cities reported increases over March in their average antiknock quality, 7 by 0.5 octane number or more. Twenty-seven cities reported decreases while six cities were unchanged.

Compared with the nationwide premium average of 99.1 octane number, eight cities reported premium averages of 99.5 octane number or higher. In regular gasoline, 17 cities showed average octane ratings of 92.5 octane number or higher, compared with the national weighted average of 91.7 octane number.

Oil Saving Money With Radioisotopes

A third of the measurable savings resulting from the industrial use of radioisotopes is accounted for by the petroleum industry, according to a national Industrial Conference Board study performed under contract with the AEC. Petroleum accounts for $11.6 million of the total U.S. industry figure of $39.2 million. NICB said the crude petroleum and natural gasoline industries saved $820,350 through isotope usage. The Board estimated that true savings were far greater, because only clearly measurable savings in costs were included in the estimates. Intangibles, although recognized as very real by the companies surveyed, weren't included. Cited in the report was one large petroleum refiner who, through the use of catalyst circulation meters representing a cost of $2,400 is able to produce $2 million worth of additional gasoline at "no increases in production costs."

U.S. Oil Reserves Hit Record High in '58

Despite a slackened rate of drilling activity in the forepart of the year, the U.S. oil industry managed to stage a comeback in 1958, and added materially to the nation's proved reserves of crude oil, natural gas liquids and natural gas.

Proved reserves in all three categories are now at all-time peaks, according to the API and AGA joint annual report on the status of these supplies of liquid hydrocarbons and natural gas.

Proved reserves of oil and natural gas are those which experience indicates can be recovered by production systems now in operation. They do not include oil in unproved portions of partly developed fields, or in stratas favorable to the accumulation of oil, but as yet untested.

The upsurge in the 1958 proved reserve statistics, which surprised many oil men, compensated somewhat for the 1957 report, which had shown a net decline for the first time since 1943.

Highlights of the 1958 report, covering the calendar year ending December 31 and representing the estimates of the reserves committees of the two trade associations, are as follows:

- Crude oil: 30.5 billion barrels, up 235 million over last year, and 101 million over the previous all-time high in 1956.
- Natural gas liquids: 6.2 billion barrels, an increase of 517 million over 1957, and 302 million over the former peak in 1956.
- Total liquid hydrocarbons (crude oil and natural gas liquids): 36.7 billion barrels, up 752 million over 1957, and 403 million over the previous record high in 1956.
- Natural gas: 254.1 trillion cubic feet, an increase of 7.6 billion cubic feet over 1957, the previous peak.

Contributing to the increases in the 1958 totals of proved reserves is the fact that production of crude oil, natural gas liquids and natural gas all declined slightly during the year.

The reserves committees estimated production of crude oil

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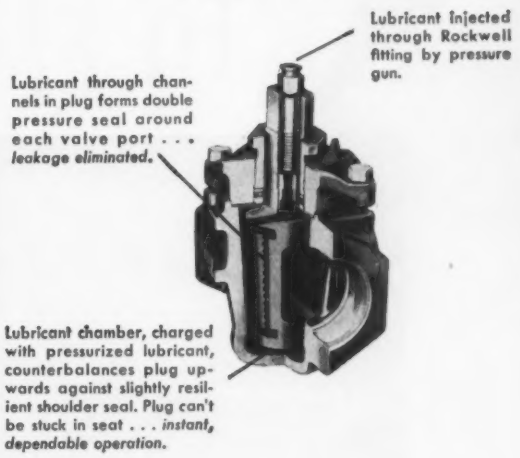
Here's why Rockwell-Nordstrom valves work better, easier and cost less to use, thanks to

$$\triangle F/A = \triangle p$$


Lubricant injected through Rockwell fitting by pressure gun.
Lubricant through channels in plug forms double pressure seal around each valve port . . . leakage eliminated.
Lubricant chamber, charged with pressurized lubricant, counterbalances plug upwards against slightly resilient shoulder seal. Plug can't be stuck in seat . . . instant, dependable operation.

The drawing above shows how lubricant in Rockwell-Nordstrom valves assures the bottle tight shut-off, smooth, easy operation and unmatched dependability that users have learned to expect over the past forty years. Rockwell-Nordstrom, the *original* lubricated plug valve, is also the world's most complete line. They cost no more to buy, often less, than ordinary valves. Whatever your valve needs, there is a Rockwell-Nordstrom valve that will do the job better, longer and at lower cost. If you'd like to know more about these valves or if you'd like to talk with a Rockwell field sales engineer, write Rockwell Manufacturing Company, Pittsburgh 8, Pa. Canadian Valve Licensee: Peacock Brothers Limited.

ROCKWELL-Nordstrom VALVES

it's ROCKWELL

MANUFACTURING COMPANY

at 2.4 billion barrels, down 186 million from 1957; natural gas liquids at 341 million barrels, down 11 million; and total liquid hydrocarbons, 2.7 billion barrels, down 197 million.

Natural gas production declined 17 billion cubic feet in 1958 to 11.5 trillion cubic feet.

The bulk of the increase in liquid hydrocarbons reserves came from revisions of previous estimates and extensions of old pools. New reserves discovered in 1958 in new fields and in new pools in old fields amounted to only 423 million barrels of the over-all total of 3.5 billion barrels of new liquids found.

MCA Chemical Industry 1958 Construction Survey by Category

Category	BY THOUSANDS			
	Planned	Under Construction	Completed	Total
Organic Chemicals (General)	152,940	246,730	401,763	801,433
Petrochemicals	22,000	53,050	164,700	239,750
Plastics & Resins	54,700	173,850	164,195	392,745
Synthetic Rubber	.....	29,000	24,523	53,523
Synthetic Fibers	59,500	54,400	140,300	254,200
Fertilizer Chemicals	41,000	22,200	52,575	115,775
Inorganic Chemicals (General)	40,800	327,640	428,770	797,210
Laboratories	27,425	59,600	70,145	157,170
Metals	18,100	15,450	141,207	174,757
Miscellaneous	47,625	72,245	187,345	307,215
Totals	$464,090	$1,054,165	$1,775,523	$3,293,778

Chemical Plant Construction Levels Off

About $1 billion will be spent for chemical production projects presently under construction, and an additional $464 million is already planned for 1959-60, according to the Manufacturing Chemists Association. In releasing results of its annual construction survey, the association said an additional $1 billion will be spent for projects underway and $464 million for those scheduled for ground-breaking soon and completion before 1961. This brings total chemical plant construction to about $3.3 billion for the three-year survey period, 1958-60.

The combined expenditure represents 802 projects by 287 companies. The $1.5 billion total for projects under construction and planned (1959-60) is more than $1 billion under the $2.54 billion listed last year. This decrease is due partly to cutbacks made during the recession months of mid-1958. By the end of the year, however, construction had begun to accelerate. Also reflected is a general leveling off of the chemical industry's requirements for new facilities. This is not considered alarming, however, because long-term goals, established after World War II to meet the demands of a projected population increase and a rising economy, are being generally realized.

Texas, with $662 million, again has the highest total figure for the three survey divisions of Planned Construction, Under Construction and Completed (1958) Construction.

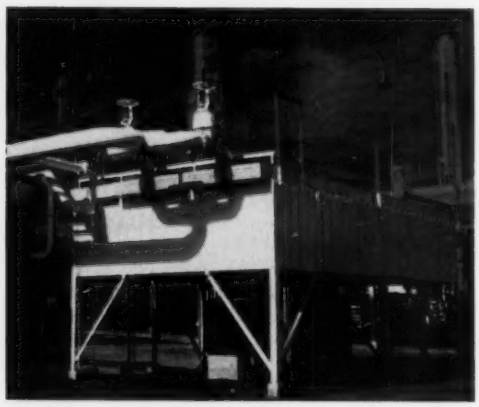
The top 10 chemical-producing states, ranked according to value added by manufacture, are New Jersey, Texas, New York, Illinois, Pennsylvania, Ohio, Michigan, California, Tennessee and Virginia.

Arkansas, Louisiana, Oklahoma and Texas again lead in total construction by region for the three-year survey period with a collective figure of $1.2 billion.

In the classification by product category, the estimated 1958-60 total investment in new production facilities for general organic chemicals tops the list at $801.4 million.

General inorganics are in second place with $797.2 million, followed by plastics and resins, $392.7 million; synthetic fibers, $254.2 million; petrochemicals, $239.7 million; metals, $174.8 million; chemical fertilizers, $115.8 million; syn-

Hi Fi SET?



Yes, SMITHCO Air Cooled Heat Exchangers DO have Hi Fidelity — they are engineered to provide faithful service long after others have ceased to operate.

A SMITHCO Heat Exchanger compares in other ways with a precision built Hi Fi set. For example, you wouldn't buy a Hi Fi in which all electrical connections were merely wrapped instead of one with conventional soldered connections, would you? Well, then, it follows that you wouldn't buy a heat exchanger with the fins wrapped instead of soldered to the tube.

SMITHCO is the ONLY major manufacturer of air cooled heat exchangers with solder bonded fin tubes. This solder bond assures the highest efficiency of heat transfer between fin and tube and has proven to be the most permanent bond yet devised.

See SMITHCO Air Cooled Heat Exchangers in action at the IPE.

SMITHCO
ENGINEERING INC

P O BOX 3217 PHONE GI 7-5545 TULSA, OKLAHOMA

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GUARANTEED PURITY!

Argon of 99.995% minimum purity

Guaranteed by LINDE!

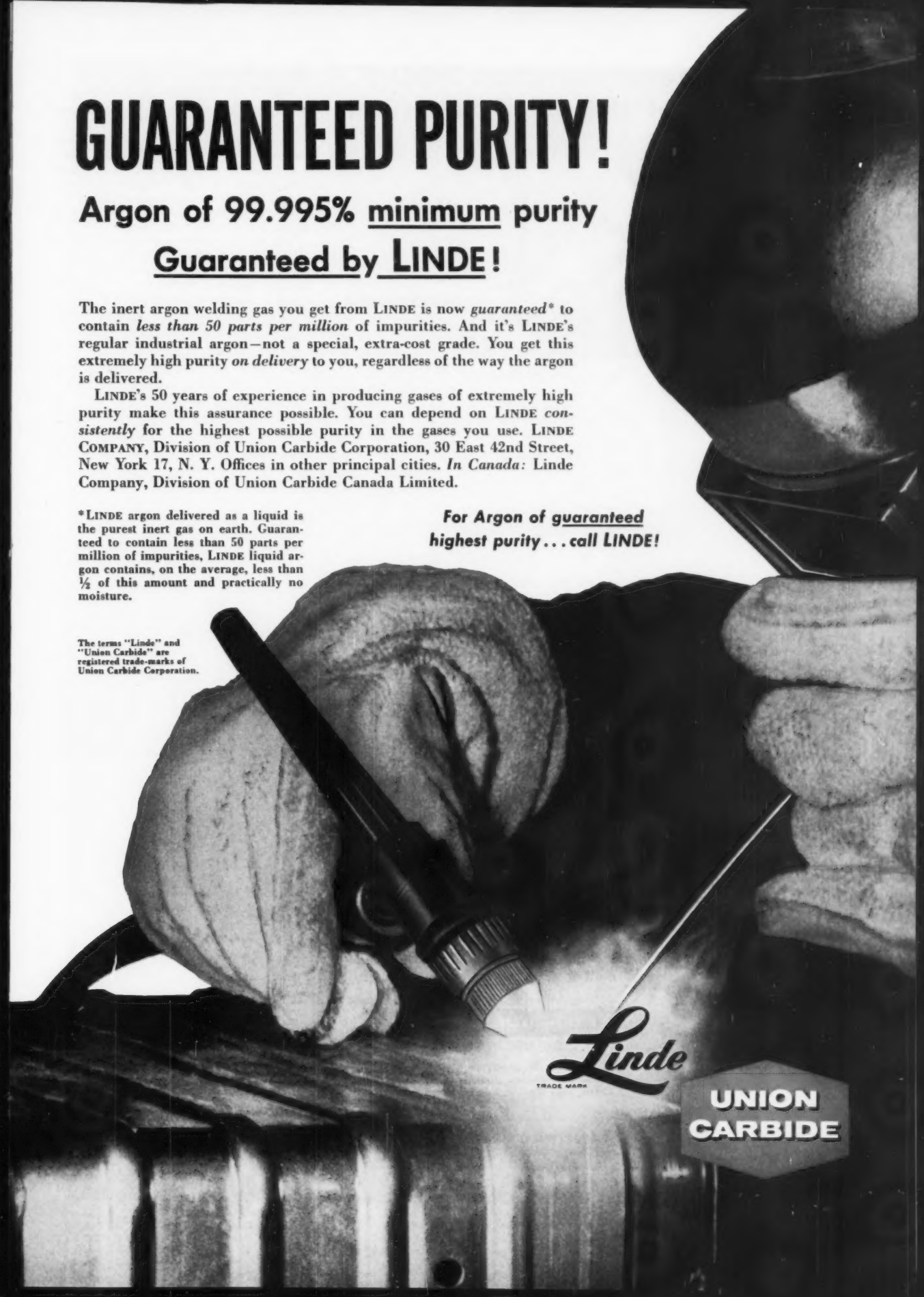
The inert argon welding gas you get from LINDE is now *guaranteed** to contain *less than 50 parts per million* of impurities. And it's LINDE's regular industrial argon—not a special, extra-cost grade. You get this extremely high purity *on delivery* to you, regardless of the way the argon is delivered.

LINDE's 50 years of experience in producing gases of extremely high purity make this assurance possible. You can depend on LINDE *consistently* for the highest possible purity in the gases you use. LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in other principal cities. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

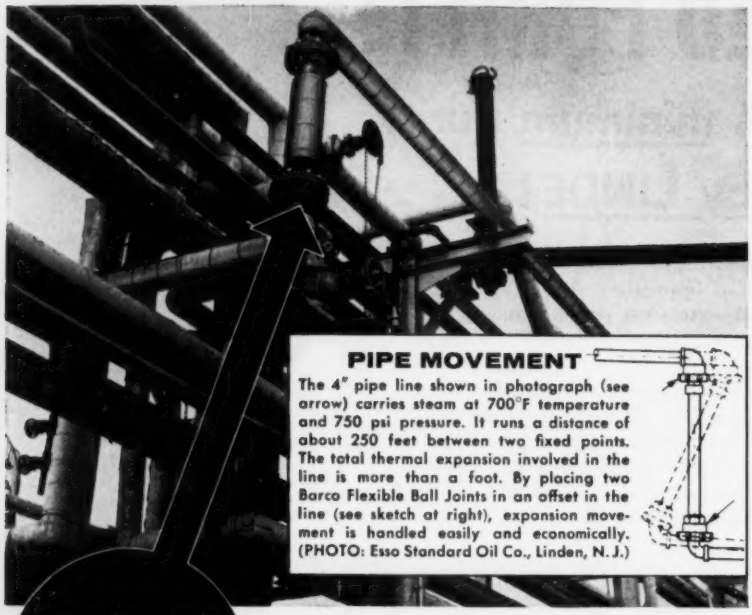
*LINDE argon delivered as a liquid is the purest inert gas on earth. Guaranteed to contain less than 50 parts per million of impurities, LINDE liquid argon contains, on the average, less than ½ of this amount and practically no moisture.

For Argon of guaranteed highest purity . . . call LINDE!

The terms "Linde" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.



How Refinery Handles 700°F. STEAM . . . PIPE EXPANSION



PIPE MOVEMENT

The 4" pipe line shown in photograph (see arrow) carries steam at 700°F temperature and 750 psi pressure. It runs a distance of about 250 feet between two fixed points. The total thermal expansion involved in the line is more than a foot. By placing two Barco Flexible Ball Joints in an offset in the line (see sketch at right), expansion movement is handled easily and economically. (PHOTO: Esso Standard Oil Co., Linden, N. J.)

A BETTER SOLUTION

BARCO HT (HIGH TEMP.) Flexible BALL JOINTS

SAVE VALUABLE SPACE

ADVANTAGES:

SAVE SPACE—Barco Ball Joints are used to perform functions similar to U-bends or pipe loops—But with much less space required and often LOWER COST.

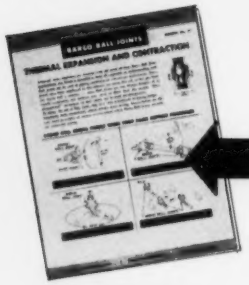
NO PRESSURE THRUST—Expensive anchoring or bracing not required to hold piping in place or in line.

HIGH TEMPERATURE, PRESSURE—Wide choice of materials in new Barco HT Joints.

SIMPLE—Easy to solve virtually any problem with aid of two or three Barco Joints.

The Barco HT (High Temperature) Flexible Ball Joint is a new development. It is *the key* to solving many PIPE EXPANSION PROBLEMS where high temperatures and pressures are encountered. The outer sealing gasket is a special, high temperature ring. The inner take up ring is self-adjusting to thermal expansion and maintains tight sealing action without building up high resistance (friction) to turning or angular flexing. HT joints can be supplied in sizes from 1" to 12", angle or straight, and can be fabricated from materials to withstand as much as 1000°F, 1200°F, or even 1400°F, under certain conditions.

Local Barco Field Engineers will be glad to give you full information and recommendations. Call or write today.



Send for this BULLETIN 31

"How to Solve Piping Flexibility Problems". Complete with piping layout drawings and illustrations. Shows how to cut costs, save time, and do a better job!

PRODUCTS BACKED BY EXPERIENCE BARCO FOUNDED 1908

BARCO MANUFACTURING CO.

542F Hough Street • Barrington, Illinois

The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Rotary Joints

In Canada: The Holden Co., Ltd., Montreal

Happenings . . .

thetic rubber, $53.5 million, and laboratories, $157.2 million.

The fibers category includes only those produced by chemical synthesis. Chemical products produced from petroleum and natural gas form the petrochemicals group, and the miscellaneous listing includes confidential data and construction difficult to classify more specifically.

The $157.2 million earmarked for new laboratories contains a substantial increase, despite the recession, over the $107.2 million laboratory expenditure listed in the survey last year. The 1958-60 figure includes $27.4 million for planned construction; $59.6 million for under construction, and $70.1 million for completed construction.

It is generally agreed, the MCA pointed out, that future chemical industry growth will depend largely on results of its research. The industry long has led in expenditures for privately-financed basic research, and its 1958 budget of $542 million for all privately-financed research, basic and applied, topped all other industries in that category, too.

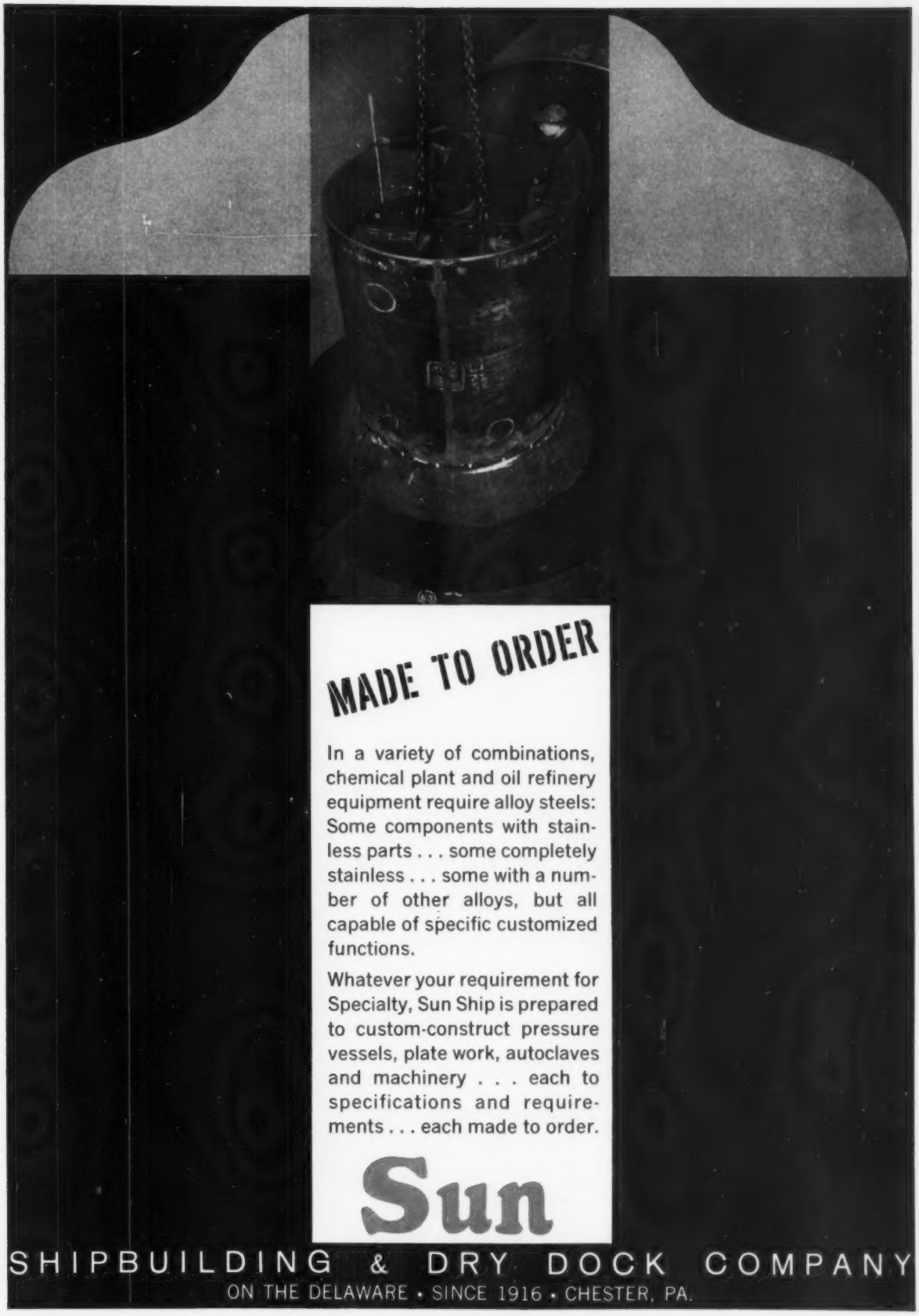
Deep-water tanker loading has been a problem because of rough, exposed sea conditions. This condition has been eliminated at Kuwait Oil Co.'s North Pier project, Mina-Al-Ahmadi, Kuwait, through use of Sheepridge Equipment Ltd.'s new tanker loading facility, pictured above. The boom rises and falls with the tide and movement of the ship—is designed to compensate for drift.

USSR Cancels Plans to Have Scientists at WPC

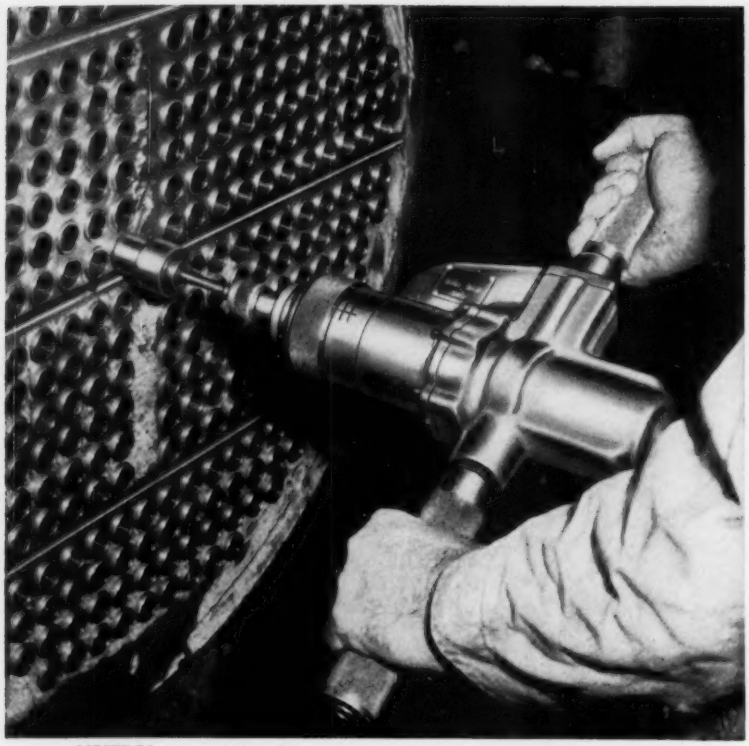
The Soviet Union has cancelled its arrangements to send oil scientists to the Fifth World Petroleum Congress. Notice of the change came from Professor A. V. Topchiev, vice president of the Academy of Science, USSR. Professor Topchiev is also chairman of the Soviet Union's Congress Committee, one of 36 established by professional institutions in as many countries to aid in organizing the New York meeting.

In his cable Professor Topchiev complains that "conditions of a discriminatory nature" have been imposed on Soviet scientists who were to attend the Congress. This refers to the State Depart-

For more data on advertised products, use Readers' Service Cards, last page.


MADE TO ORDER
In a variety of combinations, chemical plant and oil refinery equipment require alloy steels: Some components with stainless parts . . . some completely stainless . . . some with a number of other alloys, but all capable of specific customized functions.
Whatever your requirement for Specialty, Sun Ship is prepared to custom-construct pressure vessels, plate work, autoclaves and machinery . . . each to specifications and requirements . . . each made to order.
Sun
SHIPBUILDING & DRY DOCK COMPANY
ON THE DELAWARE • SINCE 1916 • CHESTER, PA.

For more data on advertised products, use Readers' Service Cards, last page.



AIRETROL pneumatic tube expansion control shown. Electric systems, including retractive units, also available.

WITH AIRETOOL TUBE EXPANSION CONTROLS, WORKERS ROLL MORE TUBES PER DAY. THEY JUST PRE-SET A DIAL AND THE TOOL SHUTS OFF AT DESIRED TUBE EXPANSION. *ACCURACY?* WITHIN .001" EVERY TIME. ELIMINATES OPERATOR ERROR. OFTEN DOUBLES DAILY PRODUCTION. WRITE FOR PLANT DEMONSTRATION OR BULLETIN.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

BRANCH OFFICES: New York, Chicago, Philadelphia, Tulsa, Houston, Baton Rouge.
REPRESENTATIVES in principal cities of U.S.A., Canada, Mexico, Puerto Rico, South America, Hawaii, England, Italy, Europe, Japan.
CANADIAN PLANT: Brantford, Ontario
EUROPEAN PLANT: Vlaardingen, The Netherlands

Happenings . . .

ment's policy not to allow the scientists from the Soviet Union to visit certain areas in the United States unless reciprocal rights to United States oil men were granted by the Soviet Union.

The Department of State has been working on an exchange of petroleum technologists with the Soviet Union for the past year, but have recently been informed that the USSR is not interested in arranging such an exchange at this time. Without reciprocity from the Soviet Union the State Department is unwilling to open any areas now restricted for travel to Soviet citizens.

NPC Plans Mobilization And Other Studies

The National Petroleum Council has established study committees on national emergency oil and gas mobilization, the use of radio and radar, and petroleum storage facilities, as requested by the government.

State Motor Fuel Taxes Hit $2.919 Million in '58

State governments collected $2.919 million in taxes on motor fuels in 1958, according to the Commerce Department. The figure was up 3.2 percent from 1957. California led all other states in motor fuel tax collections, with $301,966,000. Other states in the "$100 million and over class" included: Texas, $169,912,000; Pennsylvania, $157,284,000; Ohio, $150,-319,000; New York, $140,153,000; Michigan, $136,579,000; Illinois, $138,424,000 and Florida, $107,496,000.

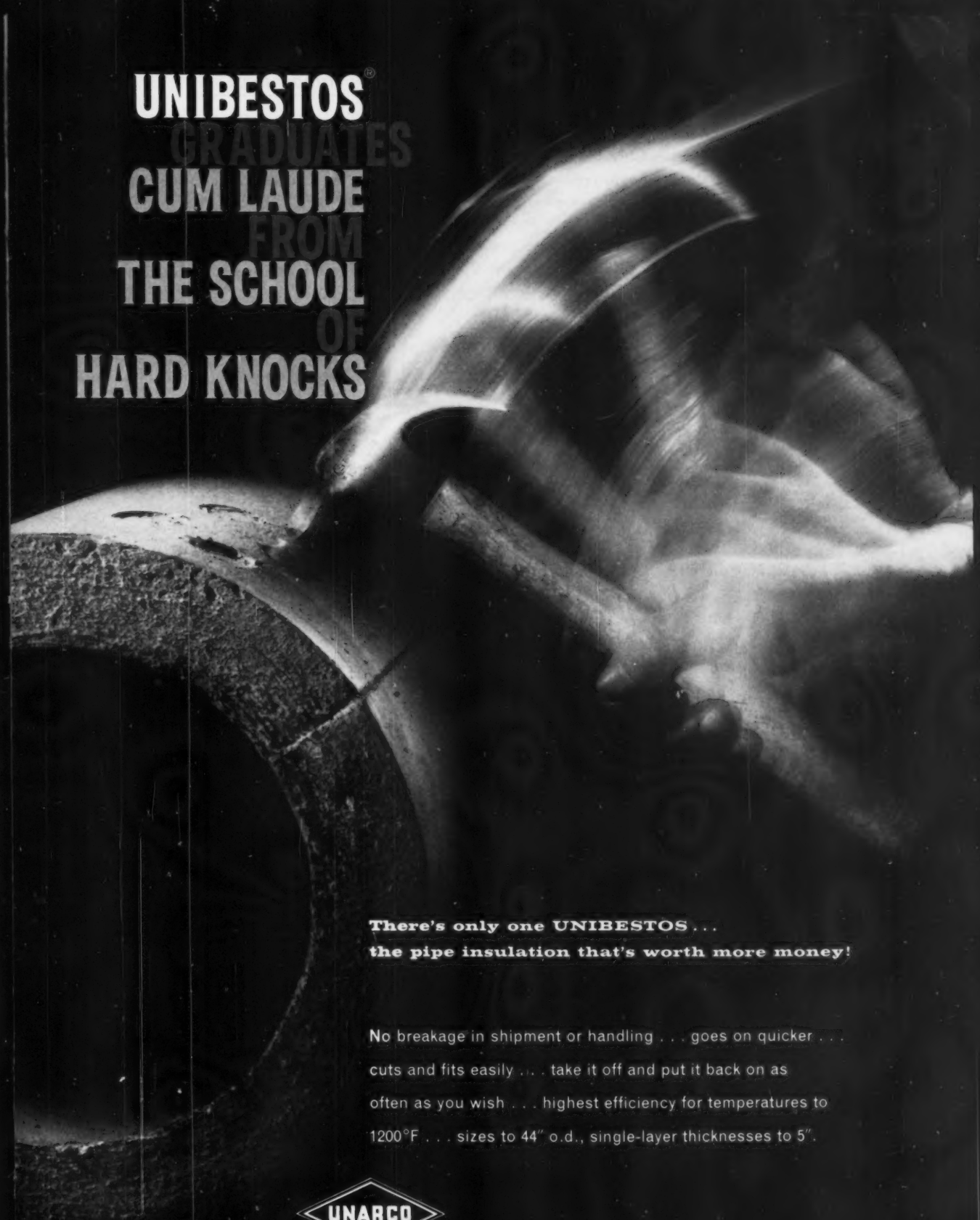
Royal Dutch Shell Group Forms Four New Companies

Four new companies have been organized by Shell Petroleum Co. and Bataafsche Petroleum Mii., N. V. They are Shell International Petroleum Co., London, for oil; Shell International Chemical Co., London, for chemicals; Bataafsche Internationale Petroleum Mij., N. V. The Hague, for oil and Bataafsche Internationale Chemie Mij., N. V. The Hague, for chemicals. The two parent companies also formed a joint "Committee of Managing Directors" to set policies and objectives and work out long range planning for recommendation to operating companies. The new companies will take over certain supply activities and responsibility for servicing and advising operating companies of the Royal Dutch Shell group throughout the world.

U. S. Natural Gas Reserves Soar to Record High in '58

Proved recoverable reserves of natural gas in the United States increased to an all-time high of more than 254 trillion cubic feet in 1958, according to an AGA report released jointly with API. A net

For more data on advertised products, use Readers' Service Cards, last page.



UNIBESTOS®
GRADUATES CUM LAUDE FROM THE SCHOOL OF HARD KNOCKS

There's only one UNIBESTOS . . .
the pipe insulation that's worth more money!

No breakage in shipment or handling . . . goes on quicker . . . cuts and fits easily . . . take it off and put it back on as often as you wish . . . highest efficiency for temperatures to 1200°F . . . sizes to 44" o.d., single-layer thicknesses to 5".

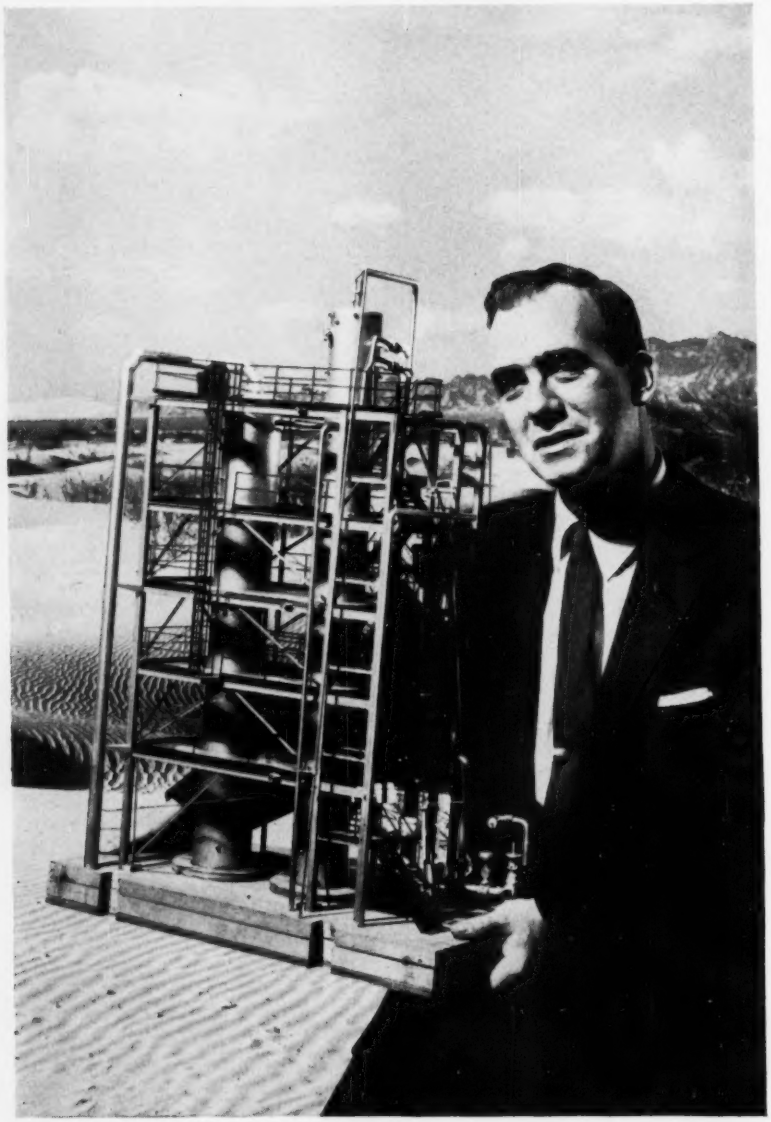
UNARCO®

UNION ASBESTOS & RUBBER COMPANY
General Sales Offices: 1111 W. Perry St., Bloomington, Illinois

Distributors in Principal Cities. Ask for free 40-page Catalog F76-321 with exclusive UNARCO "J" Factor Tables.

KEEP YOUR PLANT DESERT-DRY WITH LECTRODRYERS—It's like taking your plant to the desert if you eliminate unwanted moisture with Lectrodryers. Controls work smoothly and dependably when instruments are fed dry, clean air. Processes stay on the beam and product quality is consistently high, when the air, gases or organic liquids involved are dry. Desert dryness in warehouses safeguards products stored there.

Lectrodryers dry to dewpoints below -110°F.—in volumes of a few cubic feet or thousands per hour. Operation can be fully automatic or manually controlled. Quite likely, there are standard units to suit your needs, or we can recommend special equipment. For this help, write Pittsburgh Lectrodryer Division, McGraw-Edison Company, 307 32nd St., Pittsburgh 30, Pa.



Lectrodryer® McGRAW EDISON

Happenings . . .

gain of 7.6 trillion cubic feet was achieved during the year, even though net production in 1958 was nearly 11.5 trillion cubic feet, a one-year figure surpassed only by the all-time peak of 11,502 billion cubic feet produced in 1957.

Additions to natural gas reserves in 1958 totaled 19 trillion cubic feet, including 5.6 trillion cubic feet of new discoveries. Extensions and revisions of earlier estimates amounted to 13.4 trillion cubic feet, and an increase of 58 billion cubic feet was reported in underground storage.

The nation's estimated proved recoverable reserves have increased from 173.9 trillion to 254.1 trillion cubic feet since 1948. This net gain of 80.2 trillion cubic feet was recorded despite rapidly increasing demands. Total production during the same period was 92.4 trillion cubic feet.

New discoveries of natural gas liquids reserves in 1958 totaled 108.2 million barrels, second highest in the industry's history. Estimated reserves at year's end totaled 6.2 billion barrels, an increase of nearly 517 million barrels over the 1957 reserves total.

Canadian natural gas reserves climbed to 23.3 trillion cubic feet last year, compared with 20.7 trillion cubic feet at the end of 1957. Net production of 381 billion cubic feet was reported against reserve additions of 2.9 trillion cubic feet.

Refiners' Net Profits for '58 Down About $400,000

Petroleum refiners, including integrated companies, took a drop in 1958 profits (net after taxes) to $2.467 billion from $2.866 billion in 1957, according to a joint report from the Federal Trade Commission and Exchange Commission. Profits from the fourth quarter of 1958 were $783 million, compared with $648 million in the third quarter and $747 million in the fourth quarter, 1957.

Residual Oil Imports Called Threat to U.S. Security

Mandatory curbs on residual oil imports to wipe out a "threat to national security" have been demanded from the government by the National Coal Association. NCA's charges were filed with the office of Civilian and Defense Mobilization, which has been accepting comments on the imports situation in order to advise the Cabinet Committee on Oil Imports if and how petroleum imports endanger national security.

Exec Foresees Big Demand For LPG, Jet Fuel, Asphalt

Jet fuel, LPG and asphalt demand is slated for a big jump in the period 1959-70, Arnold M. Leas, director of technical service, Ashland Oil & Refining Co., told a NPA group recently. Domestic demand for gasoline during that period will climb

For more data on advertised products, use Readers' Service Cards, last page.

Refractory concrete stops "cat" cracker corrosion

This 250-ft. "cat" cracker, at Tidewater Oil Company's Delaware refinery, is lined with refractory concrete bonded with Lumnite calcium-aluminate cement.

These linings offer proved resistance to corrosion and abrasion – assuring top performance at high temperatures.

Such linings can also be specified for stacks, ducts, bubble towers, breechings, flues, heaters and other vital refinery equipment.

Placement of refractory concrete is easy, economical–by guniting, pouring or plastering. Concrete reaches service strength in 24 hours.

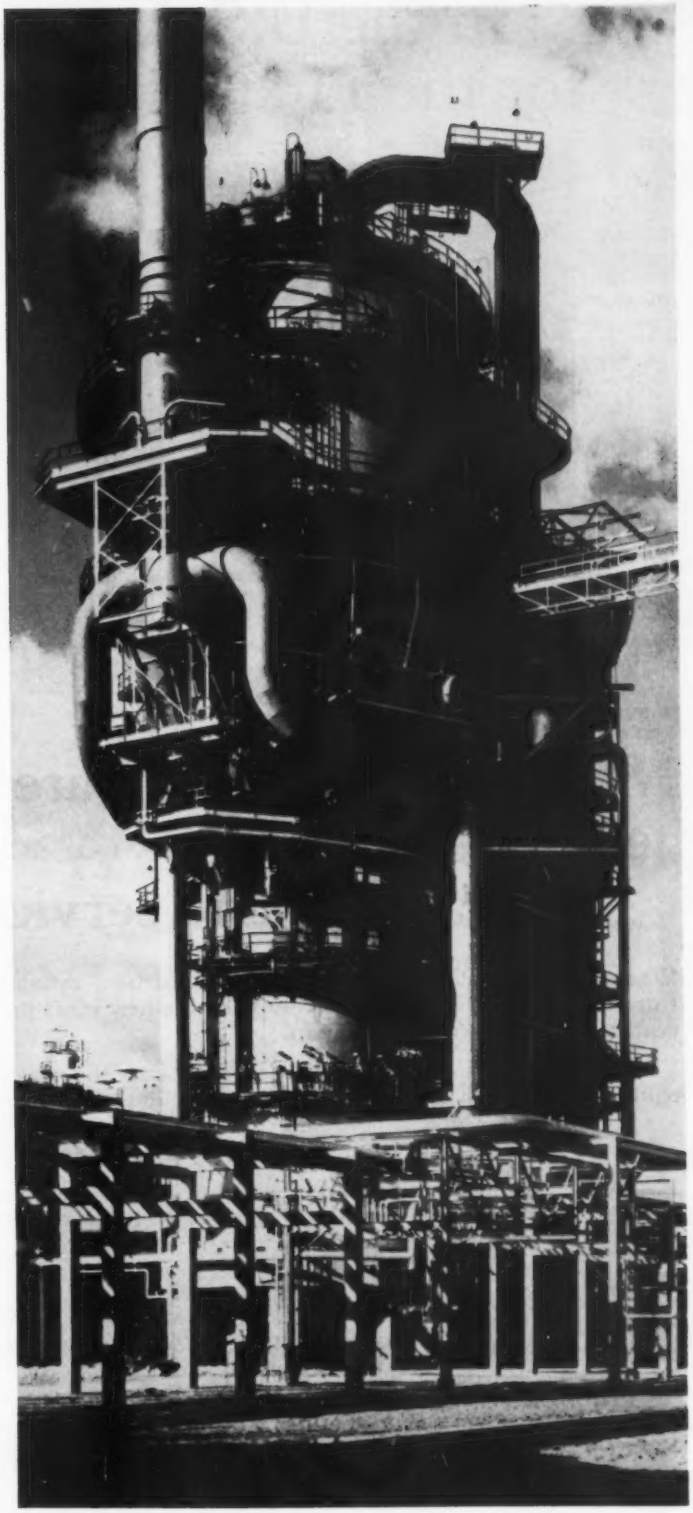
For added convenience and economy, there are castables made with Lumnite cement–packaged mixtures ready for use with just the addition of water. Available from leading manufacturers of refractories.

For more information, write Universal Atlas, 100 Park Avenue, New York 17, N.Y.

"USS," "Atlas" and "Lumnite" are registered trademarks.

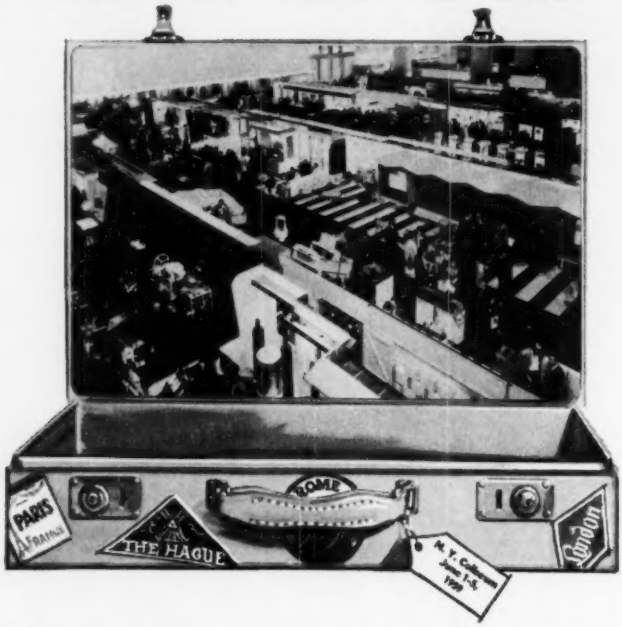
L-190

Offices: Albany • Birmingham • Boston • Chicago Dayton • Kansas City • Milwaukee • Minneapolis New York • Philadelphia • Pittsburgh • St. Louis • Waco



USS **Universal Atlas Cement Division of United States Steel**

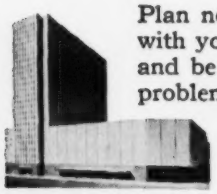
In the U.S.A. for the First Time



See, Learn and Compare the newest products, materials and services

Whatever your interest – oil research, production, refining, transportation – you will find many valuable new ideas presented at this fact-filled exposition.

You will have the opportunity to see and discuss the newest equipment, methods, services and materials with the informed representatives of some 275 leading concerns serving the petroleum and petrochemical industries.



Plan now to attend . . . and bring your key men with you. They will be reinforced with new ideas and be better prepared to cope with tomorrow's problems.

For advance registration and hotel information write the Exposition at 480 Lexington Avenue, New York 17, N. Y.

5th

WORLD PETROLEUM CONGRESS EXPOSITION

New York Coliseum

June 1-5, 1959

(Management: International Exposition Co.

Happenings . . .

at 3.8 percent per year, demand for distillate will increase 4.7 percent and demand for residual will be up an average of 3 percent per year, he said. Domestic demand for jet fuel will soar with an average annual increase of 12.5 percent, added Leas. He urged more production of middle distillate to "help build in the petroleum industry a sound economy which in turn supports necessary new expenditures for both peacetime and wartime operation."

— Changing Times —

Esso Standard Oil Co.'s Baton Rouge company newspaper, Esso News, reports that **taxes on gasoline brought more money** into state and Federal treasuries **last year than total revenue collected by government from all tax sources in first 88 years of nation's history.** State tax was $2.9 billion, Federal tax picked up additional $1.6 billion.

The Wulff Process Co. has purchased from Koppers Co., Inc., **rights to production of ethylene and acetylene under a number of its patents covering inventions of Dr. R. L. Hasche.** Company has also signed construction and engineering agreements with The Lummus Co. and The Fluor Corp.

Manufacturing Chemists Association has reported a **record low disabling injury frequency rate of 2.98** for each million man-hours worked in the chemical industry during 1958. The 1957 figure was 3.01.

Greetings from governors of several Western and Mid-Western states **will be shipped across nation through oil pipe lines** this summer as part of industry's 100th anniversary celebration. **Messages, attached to pipeline "go-devils" will be directed to Titusville, Penn.**

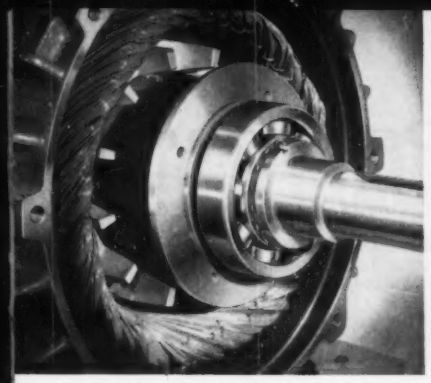
Petroleum industry was **honored for "continued and outstanding support of Junior Achievement throughout the nation** and its fostering of the youth program's ideals" at national Junior Achievement Future Unlimited Banquet, Sheraton Dallas Hotel, Dallas, May 12th.

National Safety Council's Public Interest Award for exceptional service to safety in 1958 has been awarded to Esso Standard Oil Co., Hedges Oil Co., San Francisco division of Shell Oil Co., Sinclair Refining Co., Standard Oil Co. of Calif., and Standard Oil Co. (Ind.)

The Uhde Corp. has changed its name to Hoechst-Uhde Corp. The firm is a subsidiary of Farbwerke Hoechst AG, West Germany.

North American Aviation, Inc. has offered to purchase Foster Wheeler Corp. in share for share exchange of stock. Official approval of move will be decided at stockholders meetings for both companies in July.

Transportation of petroleum products by rail entered a new era with the recent **shipment of 22,000 gallons of lube oil from Oil City, Penn. to St. Louis in a super tank car.** It is first of four such cars leased by South Penn Oil Co. from Union Tank Car Co.



HEAVY DUTY BALL BEARINGS . . . The ball bearings used in these motors are of the highest quality, with more than ample capacity to provide long trouble-free service under heavy loads.

BEARINGS CAN BE RELUBRICATED . . . Original factory lubrication will last for years in normal service—but convenient grease plugs are provided to permit relubrication that adds to motor life under severe conditions.

SECURELY SEALED FOR LOW MAINTENANCE . . . Both ends of these motors have running shaft seals to keep the bearings clean. Bearing housings are effectively sealed to prevent escape of grease.

Wagner Totally Enclosed Motors

Designed to give you Extra Protection

PROTECTED AGAINST CORROSIVE... ABRASIVE AND EXPLOSIVE ELEMENTS

WM59-7

Here are motors that will deliver full-rated horsepower under the toughest service conditions—that will help you keep your production rates up, and give you the kind of dependable, continuous operation that is so important to automation.

Type EP Motors are fully protected against damage from corrosion, dust, abrasives, fumes, steel chips or filings. Type JP is explosion proof as well—is designed and approved for use in explosive atmospheres.

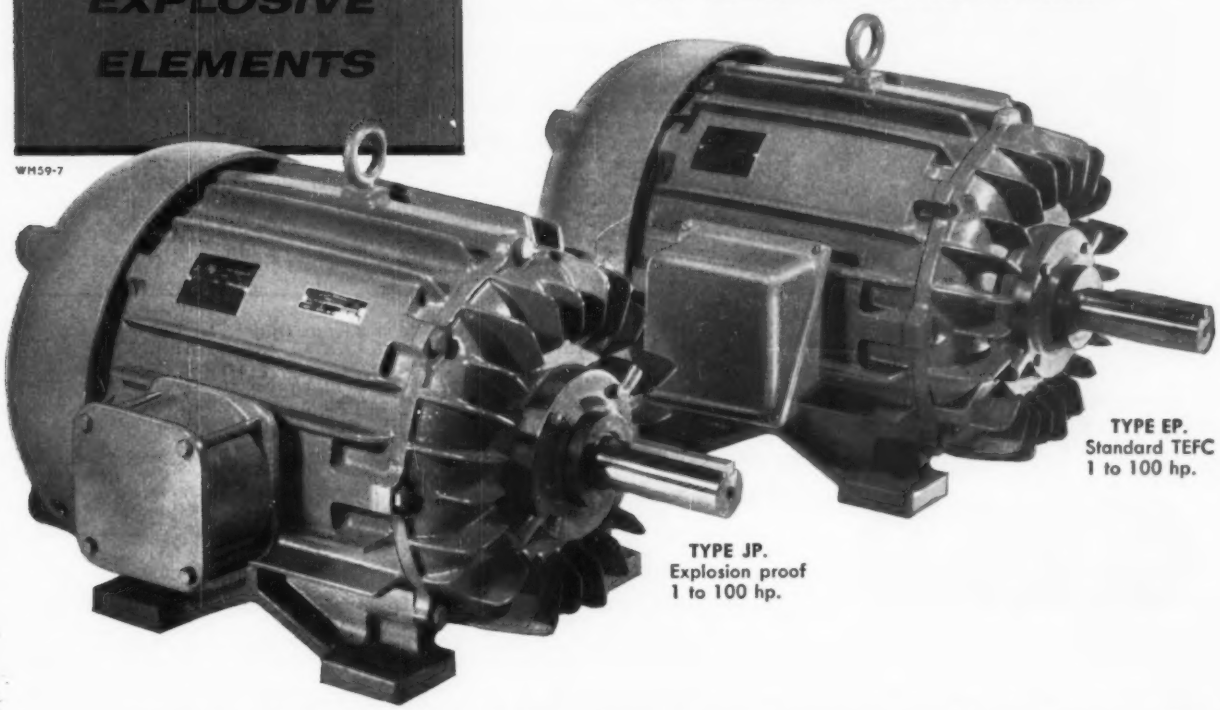
Integral ratings, 1 through 100 horsepower, are built in the latest NEMA frames, 182 through 445 US, with ribs that add mechanical strength and increase the surface cooling area.

Let your Wagner Sales Engineer show you how these protected motors can bring you savings on initial motor costs, maintenance costs, and in continuity of operation.

Branches and Distributors in All Principal Cities

Wagner Electric Corporation

6458 Plymouth Ave. • St. Louis 14, Missouri



TYPE EP.
Standard TEFC
1 to 100 hp.

TYPE JP.
Explosion proof
1 to 100 hp.

OTHER FRAME SIZES AVAILABLE IN RATINGS THROUGH 500 HP.

SERV-RITE

thermocouple extension wire in

MULTIPAIR CABLE

it cuts installation costs

When four or more pairs of thermocouple extension wires are needed, SERV-RITE thermocouple extension cable will reduce installation costs several ways. It takes considerably less time compared to pulling individual pairs of wires through conduit. Cable also permits the use of much smaller conduit than for the same number of individual wires. It can be hung without conduit, or installed in open trough or by direct burial.

The cable, as well as each conductor, is color coded. Also, each pair of wire is marked for quick identification.

Cables with multiple pairs of four or more conductors of the commonly used types are carried in stock.

Write for Bulletin No. 1200-3
for specifications and data on SERV-RITE thermocouple extension cables.

8148

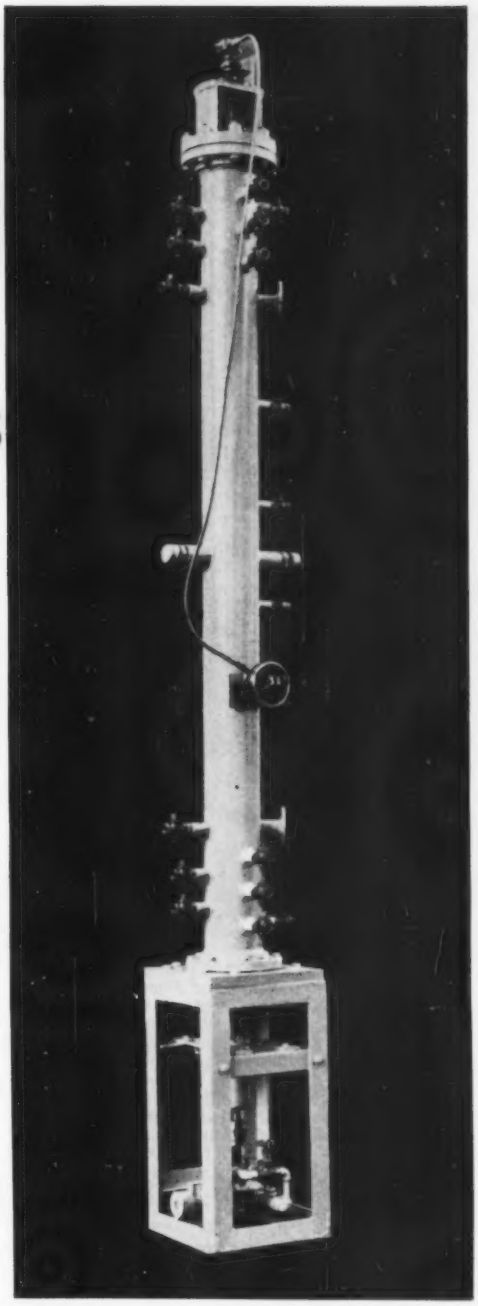
CLAUD S. GORDON CO.
Manufacturers • Engineers • Distributors

615 West 30th Street, Chicago 16, Illinois
2019 Hamilton Ave., Cleveland 14, Ohio

Meetings Calendar

May	
17–20	**American Institute of Chemical Engineers,** National Meeting, Kansas City, Mo.
18–20	**Instrument Society of America,** Annual Symposium on Instrumental Methods of Analysis, Shamrock Hilton Hotel, Houston.
25–26	**Commercial Chemical Development Association,** Spring Meeting, Pocono Manor, Mt. Pocono, Penn.
25–27	**American Society of Quality Control,** Industry Production and Quality Control Exposition, Cleveland.
25–28	**American Society of Mechanical Engineers,** Design Engineering Conference, Convention Hall, Philadelphia.
27–29	**Annual Short Course in Gas Technology,** Texas College of Arts and Industries, Kingsville, Texas.
27–30	**American Petroleum Institute** Division of Refining, Midyear Meeting, New York.
30-Jun 5	**Fifth World Petroleum Congress Exposition,** New York Coliseum, New York.
31-Jun 5	**Industrial Research Conference,** Arden House, Harriman Campus Columbia University.
June	
1– 5	**National Fire Association,** Meeting, Dennis and Shelburne Hotels, Atlantic City.
8– 9	**Industrial Water Conservation Course,** University of Michigan.
8–12	**Technical Writer's Institute,** Rensselaer Polytechnic Institute, Troy, N.Y.
10–12	**ISA,** International Symposium on Gas Chromatography, East Lansing, Mich.
14–18	**ASME,** Semi-Annual Meeting, Chase-Park Plaza Hotel, St. Louis.
14–19	**Society of Automotive Engineers,** Summer Meeting, Chalfonte-Haddon Hotel, Atlantic City.
17–18	**ASME,** Engineering Management Conference, Statler Hilton Hotel, Los Angeles.
21–26	**American Institute of Electrical Engineers,** Summer and Pacific General Meeting, Olympia Hotel, Cleveland.
21–26	**American Society for Testing Materials,** Annual Meeting Chalfonte-Hadden Hall, Atlantic City.
21–26	**Air Pollution Control Association,** Annual Meeting, Statler Hotel, Los Angeles.
22–26	**National Association of Corrosion Engineers,** Corrosion Control and Reaction Intermediate Level Short Course, Massachusetts Institute of Technology.
24–25	**Western Petroleum Refiners Association,** Mid-Continent Technical-Industrial Relations Meeting, Broadview Hotel, Wichita.
29–July 3	**Gordon Research Conferences,** Catalysis, Colby Junior College, New London, N.H.
Aug.	
10–13	**Society of Automotive Engineers,** National West Coast Meeting, Hotel Georgia, Vancouver, B C.
Sept.	
9–10	**American Society of Mechanical Engineers,** International Congress on Air Pollution, New York.
13–18	**American Chemical Society,** National Meeting, Atlantic City.
16–18	**National Petroleum Association,** Annual Meeting, Traymore Hotel, Atlantic City.
17–	**Natural Gasoline Association of America,** Rocky Mountain Regional Meeting, Casper or Calgary, Alberta.
20–23	**ASME,** Petroleum Mechanical Engineering Conference, Rice Hotel, Houston.
21–25	**ISA,** Annual Instrumentation-Automation Conference and Exhibit, International Amphitheater, Chicago.
23–24	**WPRA,** Rocky Mountain Technical-Industrial Relations Meeting, Henning Hotel, Casper.
Oct.	
7– 8	**WPRA,** Annual Stream Pollution and Waste Disposal Conference, Broadview Hotel, Wichita.
8– 9	**California Natural Gasoline Association,** Fall Meeting, Huntington-Sheraton Hotel, Pasadena, Calif.
16	**NGAA,** Southern Regional Meeting, Carlton Hotel, Tyler, Texas.
20–22	**American Standards Association,** National Conference on Standards, Sheraton-Cadillac Hotel, Detroit.
28–29	**WPRA,** Question and Answer Session on Refining Technology, Rufus Garrett Hotel, El Dorado, Ark.
28–30	**Society of Automotive Engineers,** National Fuels and Lubricants Meeting, La Salle Hotel, Chicago.
Nov.	
4– 6	**Rocky Mountain Oil & Gas Association,** Annual Convention, Cosmopolitan Hotel, Denver.
9–11	**API,** Annual Meeting, Conrad Hilton, Palmer House, and Congress Hotels, Chicago.
20–	**NGAA,** Panhandle-Plains Regional Meeting, Herring Hotel, Amarillo.

this PILOT SIZE RDC COLUMN helps you solve liquid extraction problems at low cost



Pilot data is usually required to supplement book knowledge in designing for a new liquid extraction problem. Every operation involves variations of recognized techniques that should be known *before* you begin full-scale operations.

General American is ideally equipped to help you pinpoint your requirements in advance by means of pilot-size Turbo-Mixer RDC columns.

Benzene, furfural and a variety of organic solvent extractions have been successfully piloted for commercial design.

Pilot columns are made in diameters from 2 to 6 inches, and lengths up to 8 feet. They may be purchased or leased with rentals applying to cost of production equipment; or you may ask our engineers to study your requirements in our laboratories and design and build full-scale equipment you require.

You may also obtain pilot-size Louisville dryers and Turbo bench-scale and small pilot mixers.

Most important, you have the knowledge of General American engineers, gained from years of experience with the widest variety of problems in liquid and gaseous extraction. Call or write for consultation. You'll find . . .

IT PAYS TO PLAN WITH GENERAL AMERICAN

FOR DETAILED INFORMATION AND USEFUL DESIGN DATA, SEND FOR THE FOLLOWING BULLETINS:

Please send me the following Turbo-Mixer Bulletin (s) :

General Turbo-Mixer Bulletin_____

RDC Extraction Column Bulletin_____

Process Equipment Division

TURBO-MIXERS

GENERAL AMERICAN TRANSPORTATION CORPORATION

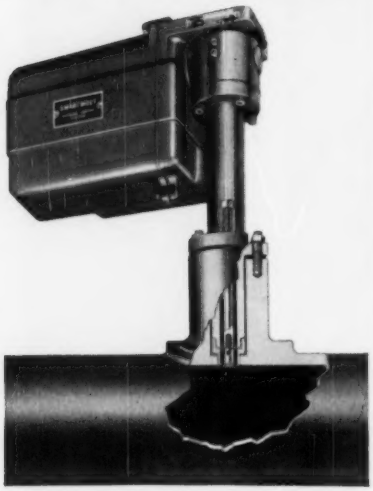
135 South LaSalle Street

Chicago 90, Illinois • Offices in principal cities

For more data on advertised products, use Readers' Service Cards, last page.

Great things are happening in AutroniC® Control

TOUGH PROBLEMS ARE NO PROBLEM



FOR THIS FOOLPROOF, FOUL-PROOF PRESSURE TRANSMITTER

Here is a primary sensing element for those tough jobs you'd like to forget. Mounted right on the process pipeline or tank, the Swartwout Flush Diaphragm Pressure Transmitter will effortlessly measure pressure or liquid level of polymers, slurries, asphalts, viscous fluids, molten metals and other difficult media. No stagnant pressure lines, no steam jacketing necessary . . . the stainless steel transmitter diaphragm fits flush with the inside of the vessel.

A friction-free linkage multiplies diaphragm motion and actuates the core of a differential transformer to produce a 0-0.5V AC signal for any Swartwout AutroniC indicator, recorder or controller. Sensitivity is better than 0.005%, reproducibility 0.1%, accuracy 1.0%.

The Flush Diaphragm Pressure Transmitter is just one unit in the constantly-growing AutroniC family of electronic instrumentation . . . a family that includes all necessary components for complete electronic control of any process parameter.

For details on the Flush Diaphragm Pressure Transmitter, request Bulletins A-713 and A-718. The Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.

SWARTWOUT

. . . world leader in electronic process instrumentation

S.A. 1958

New Books...

Air Pollution Conference

"Proceedings, National Conference on Air Pollution," covers the November 18-20, 1958, conference. Insofar as possible, it includes all of the presentations, discussions and other material pertinent to the conference, with only minor editing for conciseness.

(Department of Health, Education and Welfare, *Proceedings, National Conference on Air Pollution,* Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., 526 pages, $1.75.)

Equipment Weather Data

"Evaluated Weather Data for Cooling Equipment Design" is a summary of 10-million Summer hourly observations spanning 10 years at more than 400 official United States, Canadian and Mexican weather stations. Staff-prepared by recognized authorities, it presents in chapter and section form, among other things, (1) Temperature Variations, (2) Wet Bulb Design Values, (3) Coincident Dry Bulb Values with High Wet Bulb Values, (4) Winds related to High Wet Bulb Temperatures, (5) Dry Bulb Design Values, and (6) Interpolation Between Stations. It shows, in text and map form, the 1, 5, and 15 percent design levels of wet bulb temperatures at the various weather stations. Other values include dry bulb temperatures and wind speeds and directions coincident with high wet bulb temperatures.

Fluor Products Co., *Evaluated Weather Data for Cooling Equipment Design,* Fluor Products Co., Department DEW, Whittier, Calif., 83 pages, $35.00.)

Industrial Cooling Tower

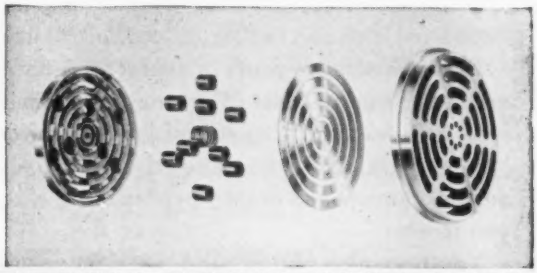
"The Industrial Cooling Tower" deals with the various approaches methods, solutions and alternatives concerning cooling towers. Data from many sources have been collected by the authors and digested along with the information provided by their own experience. The result is a homogenous and co-ordinated survey of the whole field of cooling tower technology. It aims to give broad technical and international grounding in the subject and provides both a practical approach for the theoretician and a theoretical introduction for the practician.

(McKelvey and Brooke, M., *The Industrial Cooling Tower,* D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N. J., 429 pages, $15.75. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas, U.S.A.)

Petroleum Processing Text

"Petroleum Processing, Principles and Applications," is a reference guide to the practical aspects of petroleum refin-

VOSS VALVES in your machine mean



LESS MAINTENANCE, FEWER SHUTDOWNS

for your compressor. (air, gas, ammonia)

- **up to 40% more valve area • minimum pressure loss • higher efficiency**
- **less power consumption • normal discharge temperature**
- **quiet, vibration-free • utmost safety • lower operating costs**

VOSS VALVES are made to specification, machined from solid stock (not cast)—using best alloy steels; for corrosion condition—stainless steels, such as 410, 18-8 or non-ferrous alloys—monel, inconel, etc. PLATES are machined (not stamped) and ground for precise close tolerance fit; are dimensionally stable . . . ductile . . . resist fracture, high temperatures and corrosion . . . withstand fatigue. SPRINGS of heavy rectangular sections and large diameters, add to dependability and safety.

Our detailed proposal will be sent without obligation. Send name, bore, stroke and speed of machine.

J. H. H. VOSS VALVES REG U.S. PAT. OFF.

J. H. H. VOSS Co., Inc.
785 East 144th Street, New York 54, N. Y.

Blaw-Knox builds pace setting nitrogen plant for Columbia-Geneva Steel Division of U.S. Steel Corporation. This is the first U.S. installation in a major steel plant to use coke oven gas as the source of hydrogen for ammonia production. Located near Provo, Utah, the new plant includes administration, maintenance and compression buildings . . . ammonia synthesis, storage and shipping . . . nitric acid production, ammonium nitrate production, prilling, packaging and shipping.

U.S. STEEL MAKES NEW ADVANCE IN CHEMICAL OUTPUT

Anhydrous ammonia, oxygen, sulfuric acid, nitric acid, ammonium nitrate solids and solutions . . .

A world wide effort: From Italy, Montecatini provided processes for gas purification, ammonia synthesis and nitric acid production. From Germany, the German-Linde Company supplied low temperature air and gas separation units . . . and, for the first time in this country, the famous Lurgi process is used for sulfuric acid production.

Blaw-Knox Company, Chemical Plants Division with headquarters in Pittsburgh. Branch offices in New York, Chicago, Haddon Heights, New Jersey, Birmingham, Washington, D. C., and San Francisco.

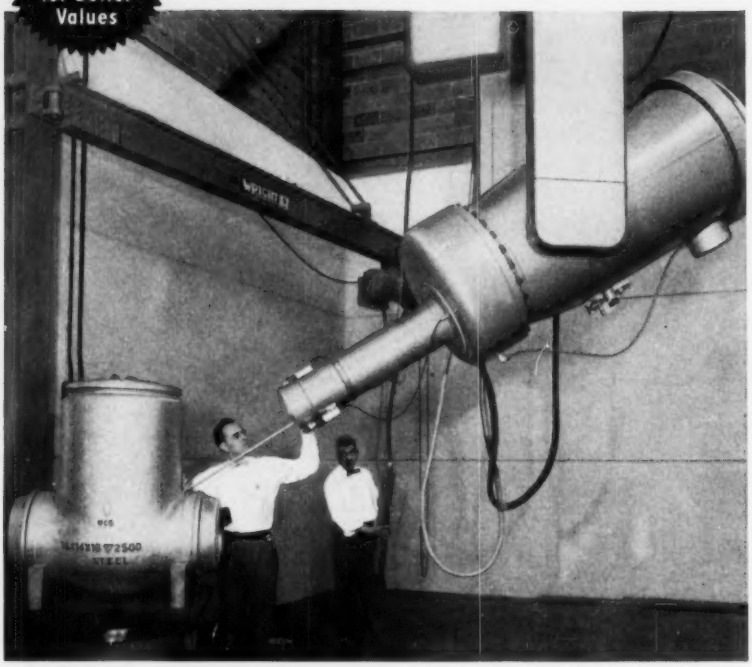
for plants of distinction . . .

BLAW-KNOX

For more data on advertised products, use Readers' Service Cards, last page.

ACCO for Better Values

Meet us at the IPE, Tulsa, Oklahoma Building, May 14-23, 1959



We look thru steel for your protection

• The 2 million volt Van de Graaff radiographic X-Ray generator, shown above, was purchased by R-P&C to provide the positive Quality Control vital to the production of High Pressure Valves and Castings.

Supplemented with a 10 Curie Source of Cobalt 60, under A.E.C. license, this equipment is housed in a special building with walls of dense concrete 48 inches thick, necessary to contain the radiation.

Constant increase in Heat Temperatures and Pressures to which valves and castings are subjected, make relatively minor internal defects critical in many installations. Therefore, use of this X-Ray equipment is now an integral part of our inspection procedures. It offers another assurance of superior R-P&C valve quality.

Regardless of the severity of your service conditions, you can safely rely on the Quality and Dependability of R-P&C Valves. Your R-P&C distributor can supply you promptly with any of these valves including gate, globe, angle and check valves in bronze, electric furnace iron and cast steel, and forged steel; all in a wide range of sizes, styles and pressure classes. R-P&C also offers specialties such as Lubrotite gate valves, bar stock valves, asbestos packed cocks, cast steel fittings and pressure-seal cast steel valves.

R-P&C VALVES

ACCO

R-P&C Valve Division, American Chain & Cable Company, Inc.

Reading, Pa., Atlanta, Boston, Chicago, Denver, Detroit, Houston, New York, Philadelphia, Pittsburgh, San Francisco, Bridgeport, Conn.

Books . . .

ing processes. It is written from the technologist's standpoint. Covered are products and raw materials; general operations; separation processes; moving beds and fluidized beds of solids, pyrolysis; catalytic cracking, catalytic reforming, alkylation and polymerization; isomerization; lube oil, wax and asphalt processes; hydrogenation; acid, clay, and hydrogen treating; sweetening and mercaptin extraction. The author emphasizes practical applications, although he includes theoretical information where it contributes to understanding the applications.

(Hengstebeck, R. J., *Petroleum Processing, Principles and Applications*, McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y., 348 pages, $10.00. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas, U.S.A.)

Quality Control Theory

"Statistical Quality Control: An Introduction for Management" tells what quality control is, what it will do, how much it costs, and who does it. It covers the subject on non-mathematical terms to enable management to assess SQC's potentials. The book then discusses individual methods and their objectives. It also outlines the duties of quality control engineers, and extensively lists sources of information on particular programs.

(Allen, D. H. W., *Statistical Quality Control: An Introduction to Management*. Reinhold Publishing Co., 430 Park Ave., New York 22, N. Y., 129 pages, $3.50.)

NBS Research Highlights

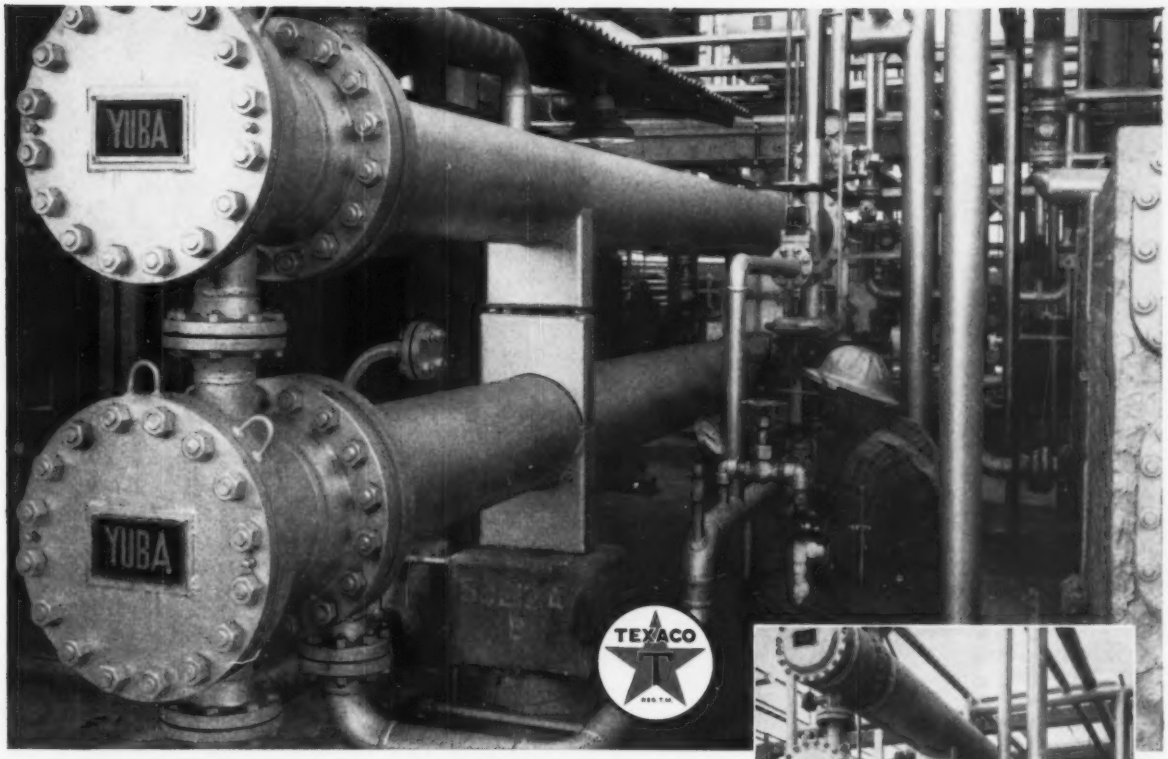
"Research Highlights of the National Bureau of Standards" highlights research and development programs for fiscal 1958 at the National Bureau of Standards. It describes a wide range of scientific studies, laboratory experiments, instrument developments and technical publications. Included is a review of the Bureau's services to science and industry through the testing and calibration of measuring instruments, and through the distribution of standard samples. The Bureau's program of cooperation with scientific and technical groups, and other government agencies, is also covered.

(National Bureau of Standards, *Research Highlights of the Nationad Bureau of Standards (Publication 226)*, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., 138 pages, $.45.)

Petroleum Refining Safety

"Safety in Petroleum Refining and Related Industries," second edition, contains sections relating to the basic causes of accidents, (1) mis-operation or improper practices, (2) equipment failure, (3) attempting to repair equipment while operating, (4) lightning, windstorm and other effects of elements, (5) improper equipment and miscellaneous causes. Provision of special equipment for accident prevention and the protec-

For more data on advertised products, use Readers' Service Cards, last page.



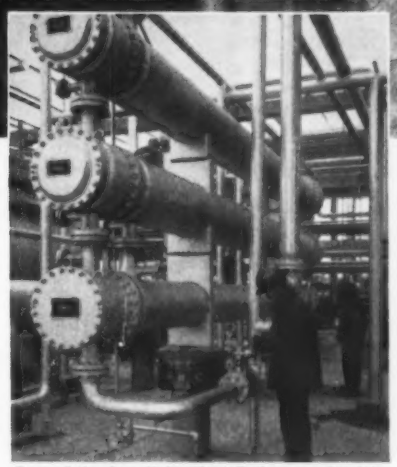
52 YUBA Heat Exchangers

perform in eight different critical processes at The Texas Company's newest refinery

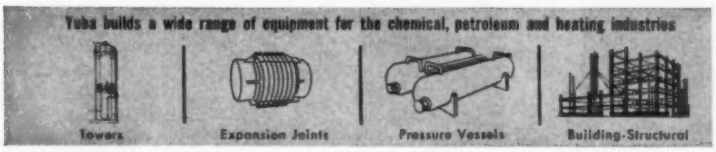
Newest of Texaco's 12 refineries in the United States, the 45,000-barrel Puget Sound Works in Washington went on stream the end of 1958.

Producing a full line of petroleum products from regular gasoline to jet fuels, this plant requires precision equipment throughout a number of different processing units. 52 precision-built Yuba Heat Exchangers, with a total of 72,991 sq. ft. of heating surface, are at work in eight of these critical processes, efficiently performing their required jobs in a temperature range of 75° to 600° F, and pressures up through 650 psi.

Here is another example of how Yuba works with the petroleum and chemical industries to achieve the optimum combination of heat economy, efficiency, and resultant lower costs. For your next heat exchanger job call on Yuba. Rating and designing services, as well as complete manufacturing facilities, located both East and West to serve you best.



Two of the four Yuba Heat Exchangers (top) in the Cat Poly Unit. The three units above are in the plant's Alkylation Unit. Below: aerial view of the refinery on its 833 acre tract. Yuba Heat Exchangers can be equipped with exclusive *Multilok Closures* for higher pressures through 6,000 psi, and temperatures to 1200° F.


Yuba builds a wide range of equipment for the chemical, petroleum and heating industries
Towers
Expansion Joints
Pressure Vessels
Building-Structural

YUBA HEAT TRANSFER DIVISION • *Honesdale, Pa.*
ADSCO DIVISION • *Buffalo, N.Y.*
YUBA MANUFACTURING DIVISION • *Benicia, Calif.*

YUBA CONSOLIDATED INDUSTRIES, INC.

Plants and Sales Offices NATIONWIDE

For more data on advertised products, use Readers' Service Cards, last page.

The CF&I Image offers you...

CLAYMONT
STEEL PLATES
made to many specifications

This giant is the Image of CF&I, reflecting CF&I's experience and versatility as one of the nation's leading primary producers of quality steels and steel products for industry.

He represents the quality controls that CF&I exercises during every step of manufacture—from ore to finished product—in the output of Claymont Steel Plates:

...**Carbon Steel Plates**—in standard ASTM and AISI specifications and special plates for special applications.

...**Alloy Steel Plates**—regularly produced by Claymont to ASTM specifications: A-387 • A-204 • A-202 • A-203 • A-225 A-302 • A-353 • A-357; also AISI specifications: 4140 • 4130. Inquiries are invited on other specifications to meet your requirements.

...**Stainless-Clad Steel Plates**—in AISI designations: 304 304L • 316 • 316L • 316Cb • 321 • 347 • 405 • 410 • 430—as well as in other specifications to meet individual requirements. Stainless cladding: from 5% to 50% of total plate thickness. Cladding inseparably bonded to carbon steel backing.

...**CF&I Lectro-Clad Nickel Plated Steel Plates**—a thick layer of metallic nickel, more than 99% pure, electro-deposited in thicknesses up to 30 mils onto carbon steel plate... provides positive protection against contamination and discoloration, at less cost than solid nickel.

...**Clay-Loy High Strength Low Alloy Steel Plates**—complies with ASTM specification: A-242. Ideal for structural and equipment applications because Clay-Loy Plates are 50% stronger than carbon steel plates of the same thickness, thus permitting weight savings up to 25% without sacrificing strength.

For complete information and order service, contact the CF&I warehouse or district sales office nearest you.

CF&I-CLAYMONT PRODUCTS: Carbon Steel Plates • Alloy Steel Plates • CF&I Lectro-Clad Nickel Plated Steel Plates • Clay-Loy High Strength Low Alloy Steel Plates • Flanged and Dished Heads • Manhole Fittings and Covers • Fabricated Steel Plate Products • Large Diameter API Pipe

Claymont Steel Products

THE COLORADO FUEL AND IRON CORPORATION

CF&I STEEL

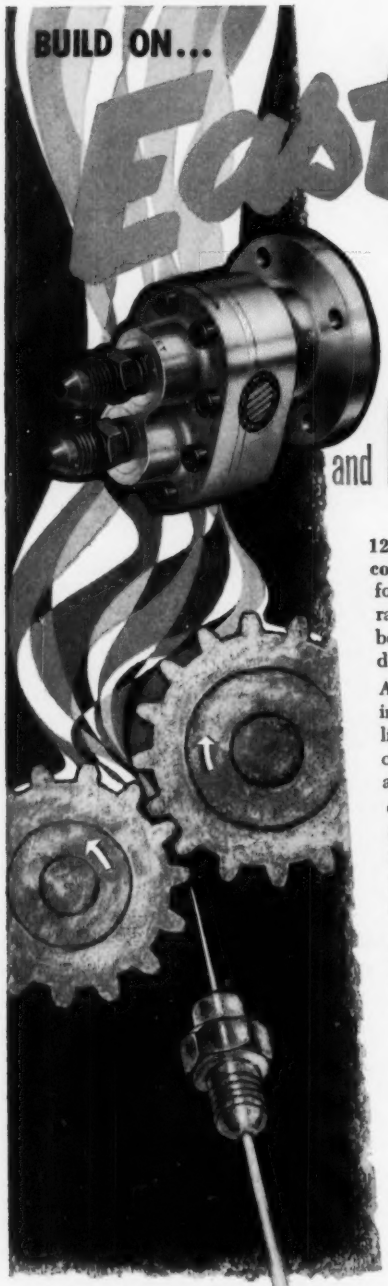
In the West: **THE COLORADO FUEL AND IRON CORPORATION**—Albuquerque • Amarillo • Billings • Boise • Butte • Denver • El Paso Ft. Worth • Houston • Kansas City • Lincoln • Los Angeles • Oakland • Odessa • Oklahoma City • Phoenix • Portland (Ore.) • Pueblo Salt Lake City • San Francisco • San Leandro • Seattle • Spokane • Tulsa • Wichita

In the East: **WICKWIRE SPENCER STEEL DIVISION**—Atlanta • Boston • Buffalo • Chicago • Detroit • New Orleans • New York • Philadelphia

CF&I OFFICE IN CANADA: Montreal

CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Vancouver • Winnipeg

6600



BUILD ON... Eastern

HYDRAULIC EXPERIENCE:

GEAR PUMPS and FLUID MOTORS

129 hydraulic pump and electric motor combinations are available off-the-shelf, for most applications. Outside this broad range, specific customer requirements can be met by drawing on Eastern's vast design resources.

All standard Eastern gear pumps are low in cost, light in weight, compact and reliable. Unique design features and very close tolerances enable each unit to achieve high volumetric efficiencies.

Check the performance ranges in these three major groups – do they meet your needs?

1200 series – up to 1.6 G.P.M. – pressures to 800 P.S.I.

100 series – up to 5 G.P.M. – pressures to 1500 P.S.I.

700 series – up to 9.8 G.P.M. – pressures to 1500 P.S.I.

In addition to these pumps, Eastern also produces a wide range of fluid motors, each capable of delivering a constant torque over a very wide speed range. They provide up to 14.5 ft. lbs. of torque at 1750 R.P.M. For full information on any one of these pumps, pump-and-motor combinations, or fluid motors, consult the Eastern sales engineer – or write for bulletin 810-R.

Eastern designs and builds

positive displacement pumps • gear pumps • centrifugal pumps

EASTERN INDUSTRIES INCORPORATED
100 SKIFF STREET
HAMDEN 14, CONN.

EASTERN INDUSTRIES PUMP DIVISION

Books . . .

tion of facilities are discussed, with special treatment given to detonative combustion, control of oil spills, tank explosion and collapse, and brittle fracture and fatigue of materials.

(Armistead, George Jr., *Safety in Petroleum Refining and Related Industries, Second Edition,* Security Publishing Co., 1000 Connecticut Ave., Washington 6, D. C., 484 pages, $12.50. For sale by Gulf Publishing Co., Houston 1, Texas, U.S.A.)

Test for Water Vapor

"Standard Method of Test for Water Vapor Content of Gaseous Fuels by measurement of Dew Point Temperature" is a correlation of the available data on the equilibrium water content of natural gases. It is believed to be accurate enough for the requirements of the gaseous fuels industry, except for unusual situations where the dew point is measured at conditions close to the critical temperature of the gas. This correlation has been approved by ASTM and is now incorporated in Section 5c of ASTM Designation D 1142-58. A set of 12 charts covering a range of pressures from atmospheric to 5,000 psia and temperatures as tabulated in the bulletin may be purchased at $2.50 per set from the Institute of Gas Technology, 17 W. 34th St., Chicago 16.

(ASTM, *Standard Method of Test for Water Vapor Content of Gaseous Fuels by Measurement of Dew Point Temperature, D 1142-58,* American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., $.30.)

Minerals Yearbook

"The 1957 Minerals Yearbook" has published the final two volumes of its three-volume series prepared by the Bureau of Mines, Department of the Interior. The latest publications are Volume II, "Fuels," and Volume III, "Area Reports." Volume I, "Metals and Minerals (except Fuels)," went on sale last December. Volume II has 480 pages and presents detailed statistics and economic information for all mineral fuels from the raw product to finished commodities. Volume III has 1,244 pages and gives details of 1957 mineral-industry developments in each State and Territory, the Commonwealth of Puerto Rico, the Canal Zone, and the island possessions and trust territories of the United States.

(Bureau of Mines, *The 1957 Minerals Handbook,* Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., Volume II, $2.25; Volume III, $4.00.)

Changed Jobs or Had a Promotion? Read "Men In Industry." Your Name May Be There!

DU PONT *Petroleum Chemicals* NEWS

Number 96 in a Series of Bulletins for the Petroleum Industry

MAY-JUNE 1959

Refiner cuts TEL unloading time in half with help from Du Pont

To solve specific problems, Du Pont offers most fully rounded line of additives

Each of the additives in Du Pont's complete line was developed to overcome a precise problem or add a performance "extra" to your petroleum product. For example . . .

1. Tetraethyl Lead—For highest octanes at lowest cost. To give you fast, dependable delivery, Du Pont maintains ample stocks at 25 distribution points throughout the U.S., convenient to refiners everywhere.

2. Fuel Oil Additive No. 2 — Improve your fuel oils with Du Pont FOA-2, the additive which stabilizes heating oils, diesel fuels and residual stocks.

3. Du Pont Dyes—A complete line of oil colors for identifying grades, meeting legal requirements and for adding brand identification to your gasoline, fuel oil, lubricants and other petroleum products.

4. Du Pont Metal Deactivator—Combats copper-caused gum in gasolines, and sludge and gel formation in fuel oils.

5. Du Pont Metal Suppressor—A newly developed product uniquely effective for coating copper parts in hydrocarbon systems and thus suppressing solution of the metal into the product.

6. Antioxidants—Protect gasolines from oxidation and gum formation. Complete line offers antioxidants for every purpose, every refinery stock.

7. "Ortholeum"® 300 — Stabilizes and protects greases. It offers the combined advantages of metal deactivation and antioxidant action.

8. Additives for industrial oils and lubricants—Three widely used and highly effective additives for improving the performance and stability of industrial oils and lubricants are:

"Ortholeum" 162 lubricant assistant
PAN (phenyl-alpha-naphthylamine)
PBN (phenyl-beta-naphthylamine)

CONTINUED OTHER SIDE

IMPROVEMENTS over an old tetraethyl lead unloading line, suggested by Du Pont engineers, made it possible to lift TEL more than 16 feet from tank car to storage level. The new line has cut unloading time in half. An additional advantage is that the new line handles both motor mix and aviation mix, thereby saving some $50,000 in unneeded new equipment. Furthermore, because of the improved time factor, one shift instead of two handles all unloading.

Changes recommended by Du Pont engineers have boosted the unloading rate at one refinery from 340 lbs/min to 800 lbs/min.

Unloading time required for 6000-gallon tank cars has dropped to less than two hours. With the old setup it took from four to six hours to unload the same cars.

The switch involved was from an old two-inch line with numerous valves and fittings to a simplified three-inch line having only two valves, two ammonia elbows and three ammonia tees.

The new design was based on careful calculations of pressure drop in both the old and proposed systems by the Du Pont representative. He then advised on the construction, tested and helped to start the operation of the new system, working at all times with the refinery engineering department.

Are you taking full advantage of Du Pont engineering know-how?

You'll find Du Pont ready to go a long way in custom-engineering service to help you solve problems involving tetraethyl lead and other petroleum additives.

Customer requests for service in the past have led to such Du Pont developments and innovations as the siphon starter, valves trimmed with "TEFLON,"® Metal-Flex unloading hose, dry dye eduction systems, and a host of other developments now widely applied in the industry.

How can you get Du Pont service?

You start by phoning or writing to the Du Pont sales office nearest you (see list on back of this page). You'll get prompt and thorough attention.

®"Teflon" is Du Pont's trademark for its TFE-fluorocarbon resin.

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

OVER

DU PONT *Petroleum Chemicals* NEWS

CONTINUED ***Complete Line***

Service also is available for the selection and handling of these additives, and in training your blending plant personnel. Your Du Pont Petroleum Chemicals representative supplies these and many other services. He's backed by a large staff of specialists in research, training, production, safety, sales promotion and advertising, men who have devoted long careers to cooperating with refiners.

Write for more information.

WEST COAST REGIONAL MANAGER

ROBERT F. HARWICK is manager of the Du Pont Petroleum Chemicals Western Region.

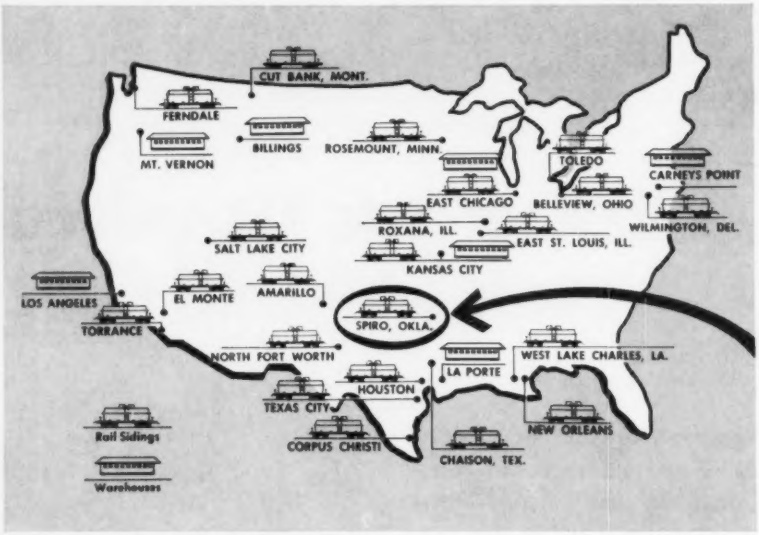
He's in charge of a variety of activities west of the Rockies. These include a Regional Sales office in Los Angeles, District Sales offices in Seattle and San Francisco, a regional laboratory and a tetraethyl lead terminal at El Monte, California, as well as additives warehouses and railway distribution centers at Ferndale, Washington; Port Costa, Antioch, Torrance, and El Monte, California; and Salt Lake City, Utah.

The new Du Pont TEL plant at Antioch makes available the TEL sold by Mr. Harwick's group.

Prior to this assignment, Mr. Harwick was the assistant manager of the Du Pont Elastomers Department's Akron office.

He brings to his job a broad range of oil industry experience, covering phases all the way from manufacturing to editorial work with a petroleum publication.

A graduate of Drexel Institute with a B.S. degree in Chemical Engineering, Mr. Harwick served for four years with the U. S. Army during World War II.



New TEL Sidetrack in Oklahoma

Now there are 22 points from which you can get emergency shipments of Du Pont TEL.

To provide even faster service to customers in Oklahoma and Southern Kansas, we are now keeping TEL on hand at a new siding at Spiro, Oklahoma.

Ample supplies of both motor mix and aviation mix are always ready to roll from all 22 sidetracks shown above. There's someone at the phone night and day at each point, ready to expedite your emergency orders.

There are also truck terminals at Carneys Point, New Jersey; Antioch and El Monte, California; Beaumont, Texas; and Ferndale, Washington, complete with weigh tanks and storage facilities, so that you can order rush shipments of TEL in less-than-tank-car quantities.

For further information on service from any of these points, contact the Du Pont Sales office listed at the right which is nearest you.

How far are you from a Du Pont additives warehouse?

Each of the seven warehouses shown on the map above is ready to make rush deliveries on any Du Pont petroleum additive whenever the need arises.

All seven maintain ample stocks of all our additives, including Du Pont Metal Deactivator, antioxidants, dyes, fuel oil additives, and grease stabilizers.

Contact any of the sales offices listed below for fastest service.

SALES OFFICES

Chicago 3—8 So. Michigan Ave. . . . . RAndolph 6-8630
Cleveland 15—101 Prospect Ave. . . . . MAin 1-3422
Houston 2—705 Bank of Commerce Bldg. . . . . CApitol 5-1151
Los Angeles 17—612 So. Flower St. . . MAdison 4-1354
New York 20—45 Rockefeller Plaza . . . . . COlumbus 5-2342
Philadelphia 2—3 Penn Center Plaza . . LOcust 8-3531
Pittsburgh 22—1 Gateway Center . . . ATlantic 1-2933
San Francisco 4—111 Sutter St. . . . . EXbrook 2-1934
Seattle 3—4003 Aurora Ave. . . . . MElrose 2-6977
Tulsa 1—1811 So. Baltimore Ave. . . . . LUther 5-5578
In Canada—Du Pont of Canada Limited, Petroleum Chemicals, 85 Eglinton Ave. East, **Toronto 12**—Ontario . . . . . HUdson 1-6461
OTHER COUNTRIES: Petroleum Chemicals Division, Export Sales, Wilmington 98, Delaware, PRospect 4-2962.

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living
. . . through Chemistry

Du Pont Tetraethyl Lead and other Petroleum Additives

OVER

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

A-10740

Printed in U.S.A.

Men In Industry...

NGAA Presents Hanlon Award To W. F. Lowe at Dallas Meet

William F. Lowe, executive director of NGAA, has been awarded the Hanlon Award, highest honor in the natural gasoline industry and one of the ranking awards in the petroleum industry. The presentation was made at NGAA's Annual Convention, Dallas. The citation read in part: "this man has been the catalyst and guiding force behind *all* NGAA activities during the last 25 years. His vision and enthusiasm have given continuity and purpose to the Association and its work throughout the years, and its outstanding contribution to industry is—in no small measure—the direct result of his energies. He . . . recognized the need for, and the value of, many cooperative studies that have become milestones of progress in our industry. Equally important, his drive and perseverance made realities of many of these ideas, and his leadership and organizational abilities in cultivating the fruits of cooperative research have resulted in improved plant technology."

Lowe is a 1924 graduate of the University of Michigan, with a degree in geology. After oil field duty with Midwest Refining Co. and as geologist scout with Midwest Exploration Co., he became technical editor for *National Petroleum News* and *International Petroleum Technology*. In 1934, he was named secretary of NGAA and was made executive director of the association in 1957.

William F. Lowe

Eber H. Peters has been named manager of petrochemical projects at Magnolia Petroleum Co.'s Beaumont refinery. He will guide chemical process and production activities. **George C. Debney** will direct all engineering, maintenance and safety work at the refinery. Assistant Technical Director **R. B. Thompson** succeeds Peters as technical director, while Assistant Chief Engineer **M. B. Tohline** follows Debney as chief engineer.

Robert T. De Vore, formerly public relations staff member, E. I. duPont de Nemours & Co., and Washington, D. C., newspaper man, has been named public relations director, Instrument Society of America. He was with DuPont 11 years.

Henry H. Beeson has been named manager of Magnolia Petroleum Co.'s Natural Gas department, Dallas. He had been assistant manager of the department since April, 1946.

Howard McCray has been named assistant to the president of The Texas Co. He joined the company in 1926 as an engineer, Port Arthur refinery. From 1940-54 he was superintendent of Texaco refineries at Sunburst, Mont.; Amarillo, Texas; Lawrenceville, Ill., and Lockport, Ill. He became manager, Operations division, Refining department, in 1954, and manager, Purchasing department in 1955.

Al F. St. Peter has been named manager of industrial relations, Delhi-Taylor Oil Corp., Dallas. He was in industrial relations from 1949-56 as staff assistant of employe and public relations of a major oil company. Since then he has been personnel manager of a Milwaukee manufacturing plant.

Thomas A. Reiter has been named a section head, Petroleum Developments division, Esso Research and Engineering Co., Linden, N. J. With the company eight years, he will work in isomerization, radiation and lube waxes.

Robert O. Law, manager of economics for DX Sunray Oil Co. since 1956, has been named manager of a new department for market research and planning, which will consolidate all marketing research services of the company. Law will headquarter in Tulsa. A graduate of the University of Denver, he holds a M.B.A. degree from the University of Southern California.

Si Ta Shiang has joined Badger Manufacturing Co. as a process engineer. He received a B.S. degree from Nankai University, China, in 1937 and a M.S. degree from M.I.T. in 1951. Shiang is a member of ACS.

Dr. Homer E. Rea has been named senior process engineer at Union Research Center, Brea, Calif. **Robert D. Doering** has been named senior engineer and **Dr. Orville L. Polly** was promoted to senior research associate.

Dr. William J. McGill, general manager of employe public relations and a director of Standard Oil Co. (Ind.), has retired. **J. Howell Turner** will succeed him. **Ray O. Traylor,** associate director of employe relations, succeeds Turner as director employe relations. **F. Roe Weise,** associate director of employe relations, will be assistant to the general manager of employe and public relations.

G. A. Wilson has been named coordinator of natural gas operations for Continental Oil Co., Houston. Formerly superintendent of natural gasoline and gas operations for the Rocky Mountain region, he joined Conoco as a roustabout in 1933 and later spent eight years at the company's Lance Creek, Wyo., natural gasoline plant. He was a process foreman at Ponca City, Okla., four years.

John R. Sabina has been named manager of the Tetraethyl Lead and Planning-section of E. I. duPont de Nemours & Co.'s Petroleum Chemicals division. He joined the company in 1937—later directed the Petroleum laboratory, Deepwater Point, N. J., and in 1944 became manager, Petroleum Chemicals section. In 1946, Sabina became technical manager, Petroleum Chemicals division.

H. W. Jouette, formerly mechanical superintendent at Magnolia Petroleum Co.'s Beaumont refinery, has been named general superintendent, mechanical, and advanced to department head status. **J. P. Thompson** has been named mechanical superintendent. **M. G. Livingston** was transferred to the Mechanical department from his staff engineer post, Engineering department. Technical director **Eber H. Peters** was named manager of petrochemical projects. He will guide refinery activities relating to chemical

Men . . .

processes and production. The company has established a second position of assistant general manager and promoted chief engineer **George C. Debney** to the office. He will direct all engineering, maintenance and safety work at the refinery. Assistant technical director **R. B. Thompson** becomes technical director, and assistant chief engineer **M. B. Tohline** will be chief engineer.

Hugh E. Kelley will head the new Planning department. Formerly head of the Economics department, he is responsible for economic evaluations of refinery activities, for all activities relating to the budget and for scheduling of crude oils and products.

W. E. McKeller, Jr., was promoted to high-level duties in the Economics department. **R. B. Kennedy,** assistant to the general superintendent, was named assistant manager of employee relations. McKellar will handle special duties in the study and preparation of budgets while Kennedy will assist in the administration of employe benefits and services.

Sydney T. Ellis has been named president of Petro-Tex Chemical Corp. Formerly executive vice president of Commercial Solvents Corp., he will headquarter in Houston.

Fred A. Davies, chairman of the board of directors of Arabian American Oil Co., has retired. Board chairman since 1952, he also was Aramco's chief executive officer until October, 1958, when President Norman Hardy succeeded him.

William P. Drews has been named an engineering associate, Esso Research and Engineering Co., Linden, N. J. Previously head of a mathematics research group in the Planning Engineering division, he will continue to work with applied mathematics and operations research.

William E. McTurk has begun a rotational assignment as assistant director of employe relations, Esso Research and Engineering Co., Linden, N. J. He had been assistant director of public relations.

John H. Johnsen, an assistant manager of Standard Oil Co. (Ind.) refinery, Sugar Creek, Mo., has been named manager of the Neodesha, Kan., refinery, effective July 1. He joined Standard in 1945 as a design engineer at the Whiting, Ind., refinery, and has held several managerial positions with the company.

Dr. Adrian LeDuc has been named a research associate by The M. W. Kellogg Co., New York. Formerly research group leader with the Electro Chemicals division Diamond Alkali Co., he will work in exploratory research. LeDuc has a M.S. degree in chemistry from Polytechnic Institute of Brooklyn and a Ph.D. degree in physical-inorganic chemistry from the University of Dijon, France.

Charles E. Webber, technical advisor to the vice president, Sun Oil Co., Philadelphia, has been named president of NGAA. Vice presidents for 1959-60 are: **Donald B. Edwards,** sales superintendent, Pan American Petroleum Corp., Tulsa; **John M. Kindle,** vice president, Lone Star Gas Co. and Lone Star Producing Co., Dallas; **Max R. Lents,** vice president, The Reef Corp., Houston; and **R. W. Heath,** vice president, Signal Oil & Gas Co., Los Angeles.

Webber

Carl A. Setterstrom has been named assistant to the president of Avi-Sun Corp. and director of the Commercial

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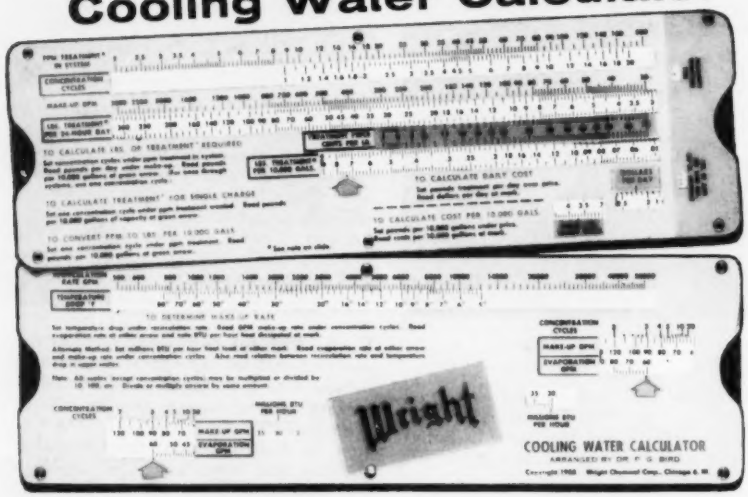

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- Treatment cost per day.
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- Treatment costs for once-through systems per day.

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This newest, improved Wright Calculator was developed in the Wright Laboratories to help keep your cooling water system operating with top day-to-day efficiency. You will find it of unusual value in your daily operations.

Wright's Engineering Service can also help you by a survey of your water system and a comprehensive water conditioning program . . . without obligation.

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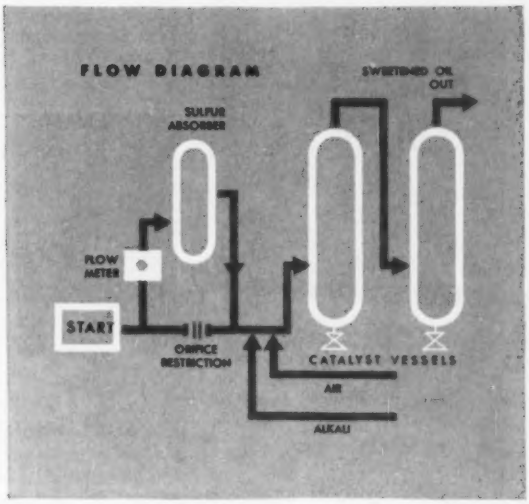

IF SWEETENING IS ONE OF YOUR REFINERY PROBLEMS...

these facts about PETRECO* BENDER Catalytic Sweetening† may show you the answer:

LOW OPERATING COSTS: The average treating costs of Petreco Bender treating units are about 0.5 cents per barrel. Copper chloride or doctor treating costs, exclusive of amortization, generally exceed 1.0 cents per barrel. *The value of the volume loss in doctor treating alone often exceeds the total operation and amortization costs of Petreco Bender catalytic sweetening.*

SWEET NON-CORROSIVE PRODUCT: As compared to doctor treating, less sulfur is used, resulting in the delivery of a consistently non-corrosive product. *The use of less sulfur also lessens octane loss.*

ELIMINATES AIR AND WATER POLLUTION: Processing is in a closed system, eliminating air pollution and the attendant safety hazards. This eliminates open batch type agitators, thereby assisting in safety programs. *There is no "black strap" carry-over or carry-under to contaminate waste disposal systems.*

The product from the Petreco Bender unit is low in trace metal ions. Where a water wash is required to meet local product specifications, emulsion problems are not encountered due to the cleanliness of the Bender treated oil.

The only spent alkali withdrawn from the Bender unit each day is the small amount not consumed in the process.

HIGH YIELD: There is no volume loss in the system other than sampling and spillage. The volume loss in other sweetening processes is the greatest expense factor.

CONTINUOUS REGENERATION NOT NECESSARY: The catalyst retains its activity for long periods of time. This is made possible by the continuous addition of small quantities of air and alkali. Catalyst life without reactivation is usually two years or more. *Two Petreco Bender plants have been operating for over three years without any reactivation of the original catalyst.*

LOW INSTALLATION COST: *Unit cost for new equipment is comparatively low, ranging from $15 to $30 per barrel of daily throughput capacity.* If existing vessels are available and appropriate for conversion, this cost can be substantially reduced. Very often the charge may be taken directly from a distillation unit with existing pumps, exchangers and instrumentation, reducing the installation cost further.

SMALL TREATING AREA REQUIRED: Where ground areas are congested, the area occupied by any treating unit is of great importance. The plot dimensions for a 5,000 bpd Petreco Bender unit, for example, would be approximately 20′ x 35′.

† *For middle range distillate streams such as kerosine, stove oil, light gas oil, No. 2 fuel oil, coker naphtha and catalytic gasoline.*

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Safety design seals against escaping gases.

Measuring mechanism in stainless steel chamber.

Scale mounted outside chamber; magnetically actuated through chamber wall.

Distinct, accurate level shown in red contrasted with silver above.

Job designed, correlating pressure, temperature, and specific gravity.

Available with electric alarms.

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Can also be used for interface indication.

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Men . . .

Development division. **Dr. Edward T.** Severs has been named product manager —polymers, Commercial Development division; and **Earl M. Honeycutt** manager of manufacturing—polymers. Named product engineers—polymers, in commercial development, are **Dr. A. Ross Adams, Neil A. Hansen** and **James C. Warren.**

Hanlon

Cassidy

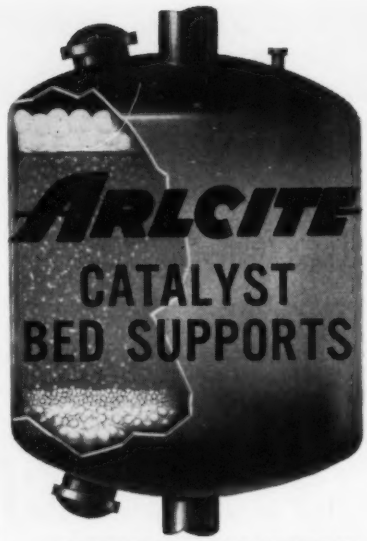
Edward I. Hanlon and William A. Cassidy have been chosen to receive special awards, along with six other pioneer oil men, at the IPE. They were selected from nationwide oil industry nominations. Hanlon, 78, will be honored as the "grand old man of natural gasoline," and Cassidy, 93, as the "grand old man of refining."

J. Howell Turner, new general manager of employe and public relations, Standard Oil Co. (Ind.), has been elected to the board of directors. Turner joined Standard as director of employe relations in 1956, coming from California & Hawaiian Sugar Refining Corp., San Francisco, where he had held the same position since 1950.

Hamilton P. Caldwell, manager of Mobil Oil Company's Augusta, Kan., refinery since August, 1957, has been named manager of manufacturing, Mobil Oil de Venezuela, with headquarters in Caracas. He will be succeeded by **Joe E. Penick** from East Providence, R. I., where he has been managing the company's refinery. He was chief process engineer at Augusta, 1952-56. **David Christison,** assistant to the manager, Buffalo refinery, since July, 1958, succeeds Penick.

Phil H. Deschner, Houston, has been promoted to assistant director of manufacturing accounting for Continental Oil Co., with headquarters at Ponca City, Okla. Formerly assistant to the controller, he succeeds **H. F. Shea,** promoted to director of the Manufacturing Accounting division.

Peter A. Blasco, former general manager of refining, Aurora Gasoline Co., Detroit, has been named vice president, manufacturing, The Vickers Petroleum Co., Inc., Wichita. A graduate of the Illinois Institute of Technology with a B.S. degree in chemical engineering, he did graduate work at Washington University. He has held technical posts with



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Scientifically compounded to "take it," Patterson Arlcite Spheres for fixed bed support and hold-down material in refining processes assure no contamination of valuable catalysts. Chemically inert and non-absorptive, these smooth-surface high alumina balls have highest resistance to thermal shock.

Arlcite Spheres offer the ultimate in mechanical strength—resistance to crushing, erosion and abrasion—and *maximum economy*, too. Field installations have extended over two years to date without replacement. Write us for the facts!

ARLCITE 86-8 Spheres are available in the following sizes: ⅛", ⅜", ½", ¾", 1" and 1¼". Immediate shipment.

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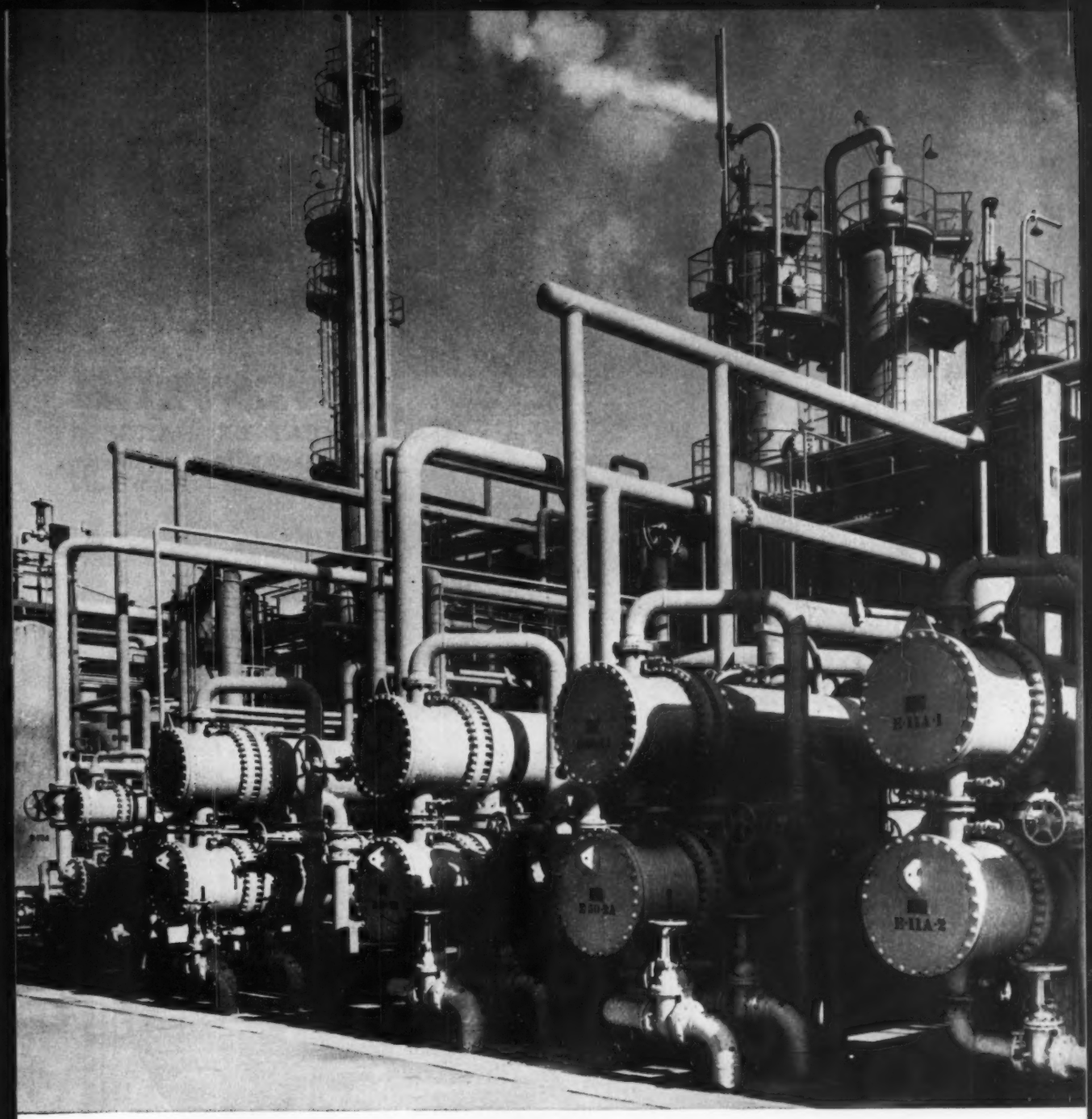
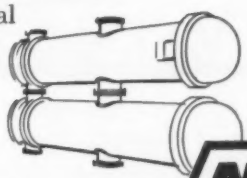


ON STREAM, ON TIME . . . these Kellogg heat exchangers, fabricated in the company's Jersey City shops, are just a few of the thousands Kellogg has put into service for leading petroleum refiners and chemical companies throughout the world. Stacked-unit fabrication techniques in the plant assure alignment and cut erection time in the field. For prompt deliveries plus design and engineering excellence at optimum cost, call Kellogg's Fabricated Products Sales Division.



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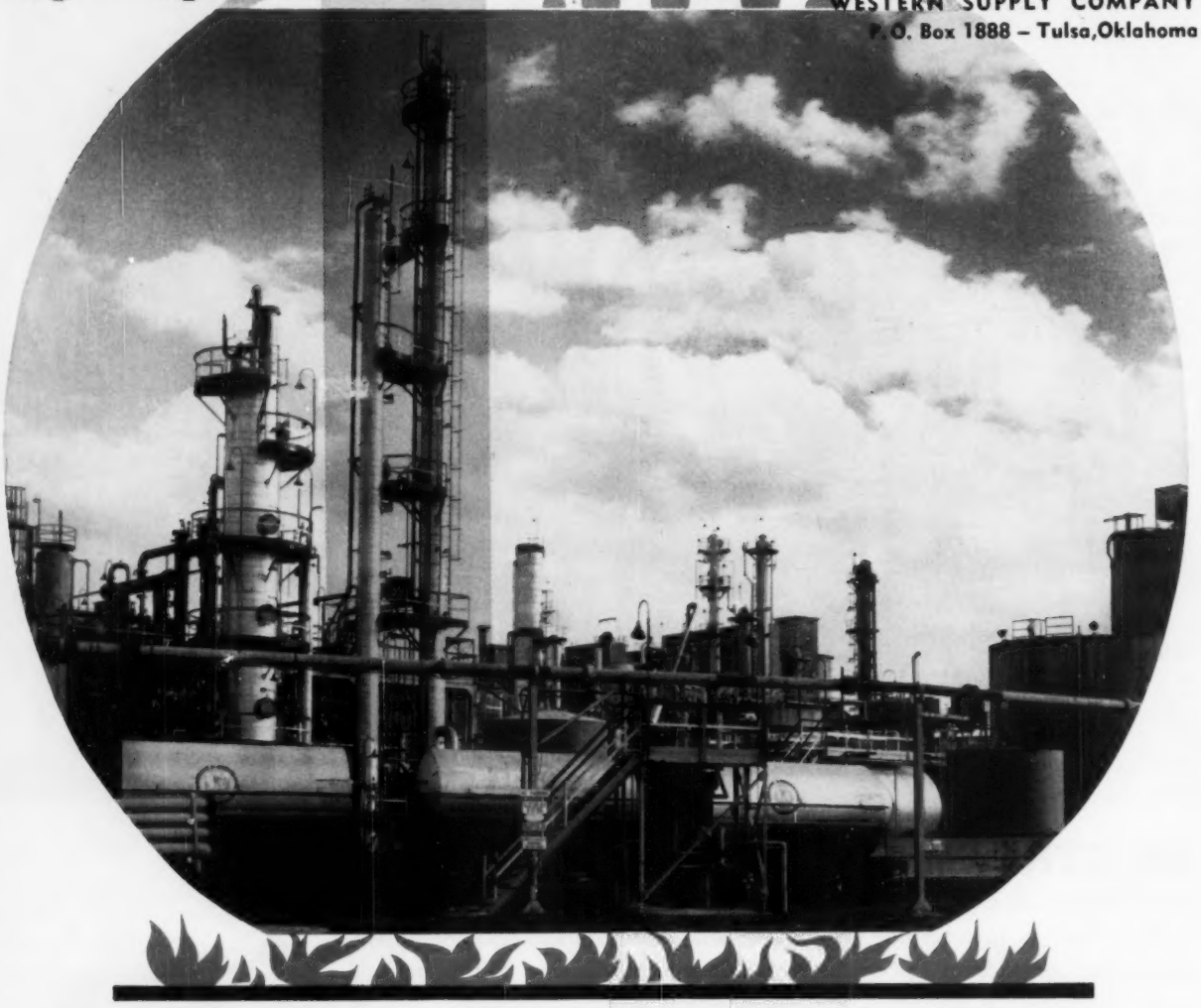

Anti-freeze is but one of many products whose origin can be traced to the South Works of Wyandotte Chemicals Corporation, Wyandotte, Michigan. In the Propylene Oxide Plant of the South Works, shown above, Western Heat Exchangers render a significant and vital service to Wyandotte's continuing growth in organic oxide chemicals.

Precise engineering, practical design and close attention to detail characterize all Western heat exchangers — tailored to the process requirements of the nation's leaders in petrochemicals.

A Western representative stands ready to help with your heat transfer requirements.

Monsanto Chemical Co., East St. Louis, Ill., and several important engineering jobs with Universal Oil Products Co., Des Plaines, Ill.

T. F. Scoggins has been named home office public relations manager, Tidewater Oil Co., with headquarters at Los Angeles.

For ten years he has been in the Shell Oil Co. Public Relations department with assignments in San Francisco, New Orleans and Los Angeles.

James W. Swaine has been named vice president of Allied Chemical Corp.'s General Chemical division. He will be in charge of the division's research, engineering, and construction activities. With the company for 32 years, Swaine has been the division's technical director since 1952. He started at the division's Baltimore, Md., works, and later transferred to General Chemical's former research laboratory, Maspeth, N. Y. He then came to New York as an administrator.

Swaine

R. B. McHenry, employe relations director for Gulf Oil Co.'s Port Arthur plant, has been named manager of employe relations. He joined Gulf in 1944 at Tulsa, as special assistant to the general superintendent of production and pipe line. He moved to the Port Arthur refinery in 1945.

P. C. Heinsohn has been appointed manager of Sinclair Refining Co.'s Southeastern division, with headquarters in Atlanta. He succeeds **E. J. Bassett,** named vice president and general sales manager for the Western region, Kansas City, Mo. **F. A. Sheriff, Jr.,** becomes assistant manager of the Southeastern division.

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Need Engineers - Technical Personnel? Try a Classified Ad in Petroleum REFINER.

QUICK! ECONOMICAL! RESULTFUL!

Help Wanted! Classified Ads in Petroleum REFINER get the job done.

Men . . .

Six new vice presidents of Phillips Petroleum Co., were elected by the board of directors following the company's annual stockholders meeting in Bartlesville, Okla. Formerly managers of their respective departments, the new vice presidents are, left to right, Harry G. Fair, Supply and Transportation department; R. B. Stewart, Natural Gas Department; G. W. McCullough, Natural Gasoline department; L. E. Fitzjarrald, Production department; E. B. Lyon, Sales department; and C. C. Tate, Refining department.

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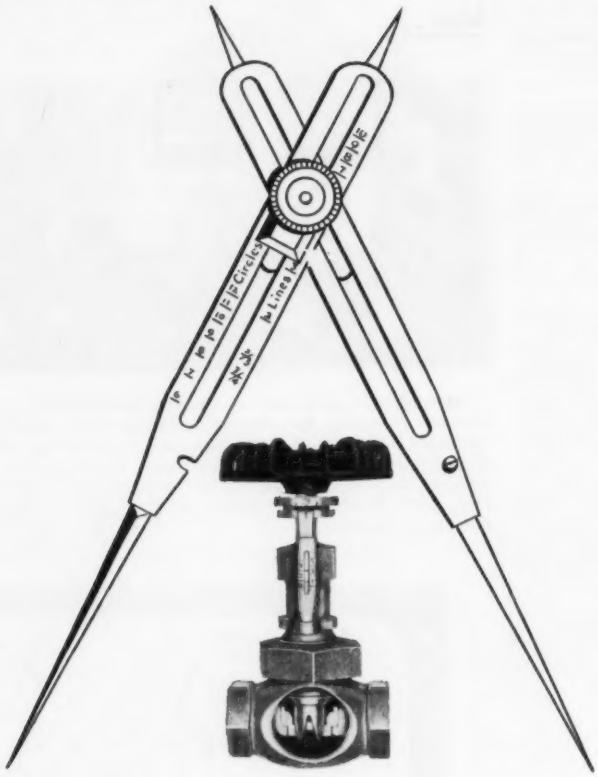
And be sure you sign up for the tour of Lummus' Engineering Development Center in Newark, N. J.



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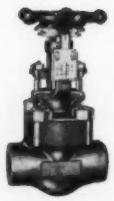
controls flow to save for you

The V-port disc in all Hancock "Flocontrol" Valves insures proportional flow throughout the entire lift of the stem. They are valves that help you achieve uniform product quality through closer control, save steam and fuel on process work, and cut maintenance costs.

"3 in 1" valve design combines variable orifice with shut-off and micrometer dial and pointer. The valve opening can be set within 1/10 turn of the handwheel —you can duplicate all settings easily, instantly. No shut-off valve required—flow is in a straight line, with separate shut-off seating surface located away from the V-ports.

Hancock "Flocontrol" Valves are available in Bronze and Steel to meet the most demanding services. Ask your industrial supply distributor for details.



Hancock "Flocontrol" valves assure positive pinpoint control—eliminate all guesswork.

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For more data on advertised products, use Readers' Service Cards, last page.

Mrs. Elizabeth Aldrich Bridgeman, a fuels technologist in the Research and Development department of Phillips Petroleum Co., Bartlesville, has been named "Oil Woman of the Year." She was chosen by a panel of top oil industry executives from among Desk and Derrick nominees from all over the country. The Desk and Derrick Club of Tulsa was the sponsor of the contest, in cooperation with IPE. Receiving honorable mention in the contest were **Miss Irma Cline,** owner of Petroleum Business Services, Inc., Hobbs, N. M.; **Mrs. Bernice W. Cleere,** oil editor, Standard-Times, San Angelo, Texas, and **Mrs. Margaret Applegate Kitchen,** senior geologist, Sun Oil Co., Mount Pleasant, Mich. Mrs. Bridgeman, holder of a M. S. degree from Tulane University, New Orleans, is credited with many contributions to the industry since 1928, when she was employed as a chemist by the National Bureau of Standards, Washington, D. C. In the intervening years she has worked extensively on analysis of gasoline quantities, and fuel requirements. She has been with Phillips since 1946.

Bridgeman

Charles E. Spahr, president of The Standard Oil Co. (Ohio) has been elected to membership on the board of trustees of Case Institute of Technology. President of Sohio since December, 1957, he is a 1934 graduate of the University of Kansas with a B.S. degree in civil engineering. He also attended Harvard Business School. With Sohio since 1939, he was elected vice president in 1955. He is a vice president and director of API, a trustee of National Petroleum Association, director of the Ohio Chamber of Commerce, and member of the Military Petroleum Board. During 1952, he served as a director of the Supply and Distribution division of the Petroleum Administration for Defense.

M. H. Cutler has been named engineering manager of Stone & Webster Engineering Corp. Formerly assistant engineering manager, he succeeds **Fred W. Argue,** named executive vice president of the company. **Thomas A. Fearnside,** chief mechanical engineer, was made assistant engineering manager. **Floyd F. Dedrick,** assistant chief mechanical engineer, succeeds Fearnside. Cutler, who had previously been chief structural engineer, joined S & W in 1923. He has done design and consulting work on industrial and chemical plants in many sections of the U.S. and Canada.

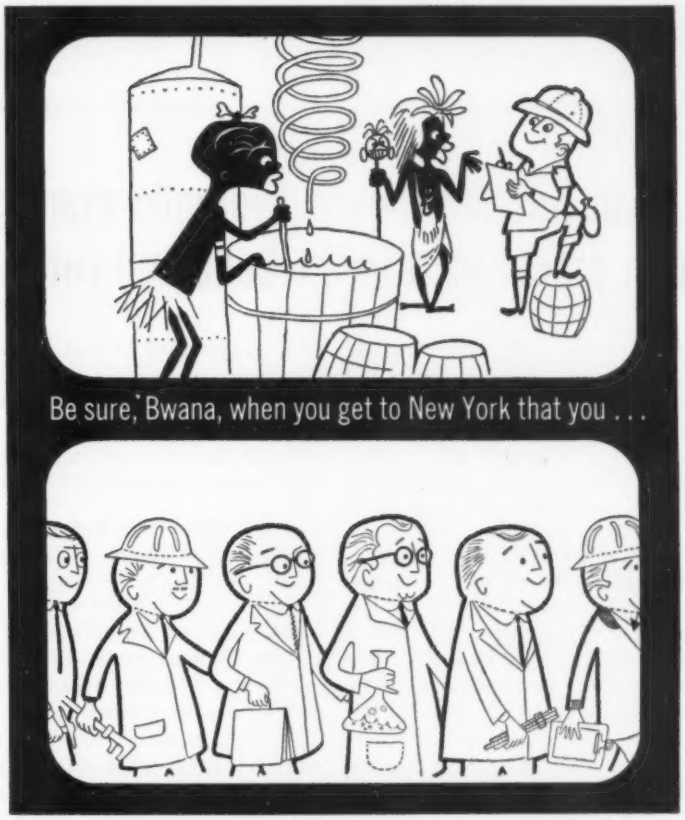
Cutler

Dr. Howard H. Hurmence has been named technical director of Allied Chemical Corp.'s General Chemical division. He succeeds **J. W. Swaine** who has been appointed vice president in charge of research, engineering and construction. As technical director, Dr. Hurmence will head General Chemical's research and development activities in industrial, agricultural and scientific chemical fields. The Division's major research laboratory is at Morristown, N. J. It also has a development laboratory at Baton Rouge, La. Dr. Hurmence became chief engineer of the division last year after acting as assistant for five years. He has been a member of the Allied Chemical organization since 1948, previously serving as technical assistant in the offices of the director of operations and president of the division.

Francisco Chairez, former chief chemist with Eastern States Petroleum and Chemical Corp., Houston, has joined National Aluminate Corp., and will move to Mexico City as manager of Mexican operations. Chairez has a B.S. degree in chemistry from Rice Institute and a M.S. degree in chemical engineering from the University of Houston. While in Houston, he was secretary-treasurer of the Engineers' Council of Houston and secretary of the Southwest District Council of ASTM. He was also active in ACS and the Houston Engineering and Scientific Society.

James A. Singmaster of New York has been appointed a member of Monsanto Chemical Co.'s Corporate Planning group. Singmaster, who will join the Planning group at St. Louis on June 1, currently is Eastern regional sales manager for Monsanto's Organic Chemicals division. He holds an A.B. degree in chemistry from Williams College and a M.B.A. degree from Harvard University. Prior to joining Monsanto in 1944, he was general manager for Casein Co. of

Men . . .



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And be sure you sign up for the tour of Lummus' Engineering Development Center in Newark, N. J.

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Two Austin-Western 5-ton hydraulic cranes work together as a precision team to handle delicate heat exchangers.

Twin Austin-Western hydraulic cranes form precision team at Cuban oil refinery

"Our first Austin-Western hydraulic crane performed its construction and maintenance duties so satisfactorily that we purchased a second a year later." That is what the manager of the Cuban refinery of a major American oil company says about the A-W 5-ton crane.

Easy to operate

"We have not lost any man-hours due to inadequate handling facilities for heavy materials . . . the A-W solves such problems before they can arise. The crane is so easy to operate that new operators can be trained in only 3 days or less. It would be encouraging to think that we could be as pleased with all future heavy machinery purchases as we have been with the Austin-Western cranes!"

The economical A-W hydraulic crane is a self-propelled, rubber-mounted unit with speeds up to 35 mph. Its basic 18-ft. telescoping boom rotates in a full circle. Choice of gas or diesel power. Maintenance requirements are low. Full hydraulic control makes precision handling of heavy materials safe and sure.

All-wheel drive and steer

All-wheel drive assures plenty of traction on any surface. All-wheel steering permits it to turn in less than its own length. It operates with amazing maneuverability in tightest quarters with low overhead clearances. Also available truck or stationary mounted.

Investigate. Learn now how this versatile hydraulic crane can speed your construction, maintenance and materials handling operations with added safety and profit. See your nearby Austin-Western distributor or write to us.

Austin 1859 AUSTIN-WESTERN 1959 100th YEAR PARTNERS IN PROGRESS Western
CONSTRUCTION EQUIPMENT DIVISION, AURORA, ILL.
BALDWIN · LIMA · HAMILTON
Power graders • Motor sweepers • Road rollers • Hydraulic cranes

BALDWIN BLH LIMA-HAMILTON

Men . . .

America. In 1951, he was appointed assistant general branch manager of Monsanto's New York office and became district sales manager there in 1953. He was appointed to his present regional post in 1957.

Robert L. Davidson, a specialist in petrochemical and petroleum processing developments, has been named executive associate of W. Alec Jordan/Associates, chemical marketing consultants and technical public relations firm. Before his present appointment, he was senior editor of *Petroleum Week,* a McGraw-Hill publication. A graduate of the University of Missouri with B.S. and M.S. degrees in chemical engineering, he has had industrial experience in petrochemicals, petroleum, solid-fuel rockets and explosives.

Quincy V. Tuma has been promoted to chief safety engineer for Texaco, Inc. He succeeds **C. A. Miller,** who retires on the same date. **Kraus Earhart,** staff assistant, replaces Tuma as safety supervisor—both to have headquarters in Houston. Tuma graduated from the University of Texas with a B.B.A. degree in 1937. Before that he was in the office at the company's Port Arthur works. In 1937 he became a clerk for South Texas (now Houston) division of the Domestic Producing department. He transferred to the Personnel department in 1938. In 1945 he was named safety engineer. After serving in West Texas, he returned to Houston as safety engineer (Research). In 1957 he was appointed safety supervisor.

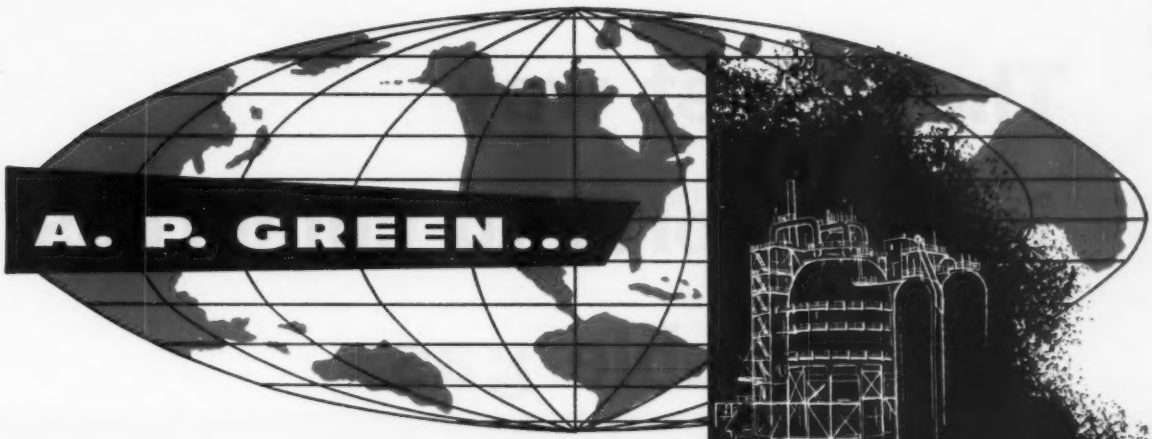
Tuma is vice president for industry of the Texas Safety Association; chairman of the Gulf Coast division, Petroleum section, National Safety Council; and is chairman of the First Aid committee and a member of the Central Accident Prevention committee, both of API.

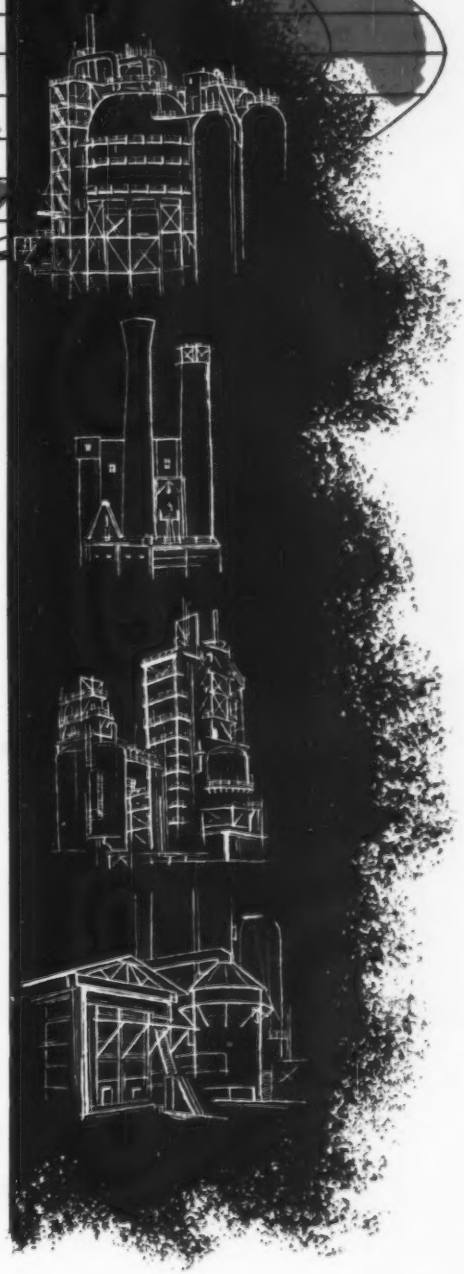
Kraus Earhart received his schooling in the Houston area. He started with Texaco in 1919 at the Port Arthur works and advanced to construction engineer at the refinery, then served as safety engineer at Tulsa and Houston. In 1947 Earhart was named representative of foreign operations. In 1956 he returned to safety operations as staff assistant.

A. F. Reed, vice president of the Lion Oil division of Monsanto Chemical Co., has retired after 30 years of service. He joined Lion in 1929 as a distributor of tank car products. He became secretary and general manager of the Lion Oil Sales Co., a subsidiary, in 1930. In 1936 he was elected director, vice president and general sales manager of Lion Oil Refining Co., which later became Lion Oil Co. He served in that capacity until he relinquished his duties in 1957 to become consultant in sales matters for both the Lion and Inorganic Chemicals divisions of Monsanto.

For more data on advertised products, use Readers' Service Cards, last page.

THROUGHOUT THE WORLD...





Serves the Petroleum Refining Industry with a Complete Line of High Quality Refractory Products

The petroleum industry, throughout the world, relies on A. P. Green high quality refractories for dependable service in thermal and catalytic cracking units, heaters, boilers, stacks, et cetera.

A world-wide network of A. P. Green distributors with engineers experienced in petroleum refining is always ready to help you select the right refractories to do the best possible job . . . at the lowest cost. For one dependable source of a complete line of refractories write . . .

A. P. Green
REFRACTORY PRODUCTS

A. P. GREEN FIRE BRICK COMPANY
PLANTS: Mexico, Mo. • Woodbridge, N. J. • Sulphur Springs, Texas • Jackson, Oak Hill, South Webster, Ohio • Philadelphia, Climax, Pa. • Troy, Idaho Pueblo, Colo. • Macon, Ga.

In Canada: A. P. GREEN FIRE BRICK COMPANY, LTD. Toronto 15, Ontario.

In England: LIPTAK, LTD. London, England.

Distributors in the Principal Cities of the World

For more data on advertised products, use Readers' Service Cards, last page.

The safest way in the world to compress inflammable gas

PROBLEM: To compress highly inflammable gaseous oxygen to 400 PSI by centrifugal compression without the inherent hazards of an oxygen-oil vapor mixture...explosion and product contamination.

CONVENTIONAL SOLUTION NO. 1: Separate oil vapors and process gas by pumping an inert buffer gas such as nitrogen into labyrinth strips between the gas and mechanical seals.

DISADVANTAGES: Buffer seal controls must operate correctly at all times. Supply of inert gas must be continuous. Product purity may be endangered. No positive seal during shutdown.

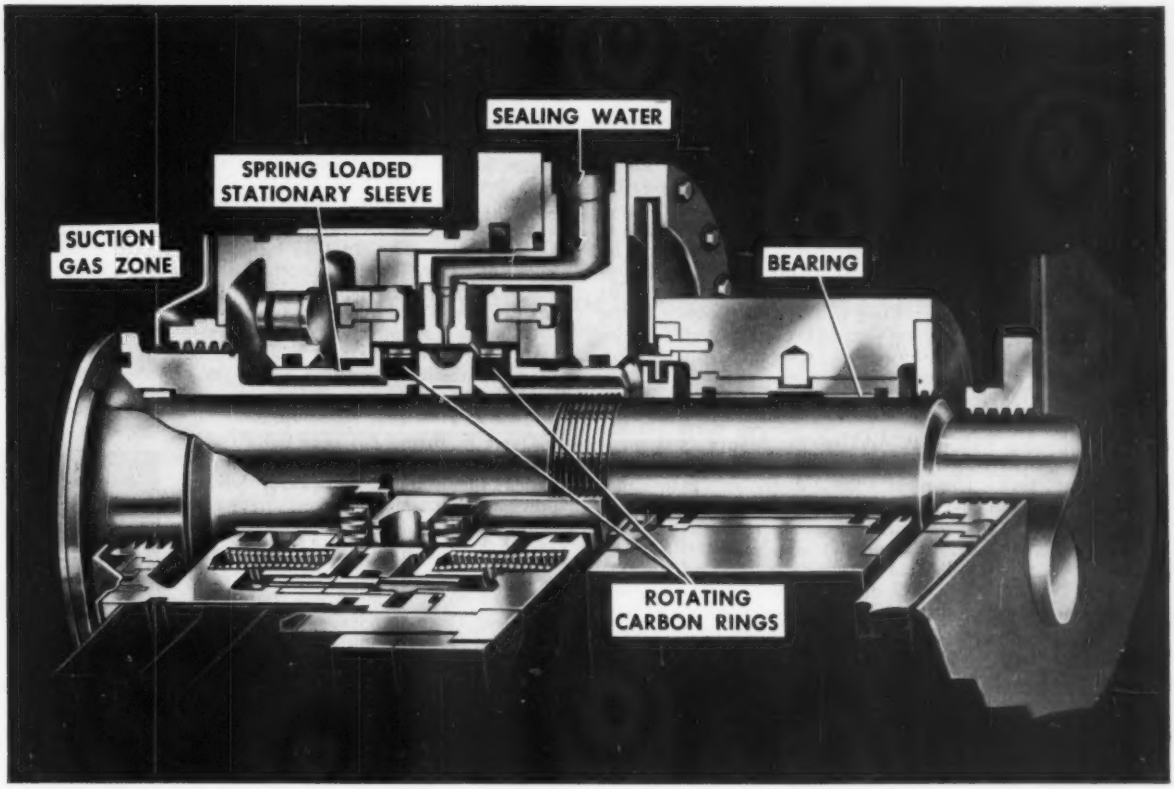
CONVENTIONAL SOLUTION NO. 2: Bleed process gas from the compressor through labyrinths in a direction opposed to the oil vapors.

DISADVANTAGES: Creates dangerous oxygen-oil vapor mixtures in seal bleeding passages. Loss of product. And no positive seal during shutdown.

CARRIER SOLUTION: Install a Carrier Centrifugal Compressor with water-lubricated iso-carbon mechanical seals. Water is pumped between two rotating carbon rings placed back to back, acts as the lubricant and assures a positive seal of the oxygen from the bearings and atmosphere.

CARRIER ADVANTAGES: Positive seal both running and shut down with no hazardous oxygen-oil vapor mixture, loss of product or contamination. Sealing water controls need not be sensitive and compressor speed or pressures have no effect on seal performance.

WHAT IS YOUR PROBLEM? Carrier has the answer in a wide range of specially-designed compressor seals. For complete information, ask your nearest Carrier office for descriptive literature on "Centrifugal Compressor Seals" (18P117). Or you can write Carrier Corporation, Syracuse 1, New York.



Carrier

Refrigeration Gas Compressors

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers Notes...

Smith

Charles T. Smith has been named assistant marketing manager, The Babcock & Wilcox Co.'s Boiler division. He was formerly sales engineer in the Philadelphia district office. Smith will be in charge of propositions and technical sales assistance for industrial boiler products, with headquarters in Barberton. He joined Babcock & Wilcox as an engineer in 1947, went with the Philadelphia Proposition department in 1951 and was made sales engineer in 1952.

Masoner

W. K. Masoner has been named technical sales representative, Tulsa, for Wolverine Tube, Division of Calumet & Hecla, Inc. Formerly with Fluor Products division as a design engineer, Masoner will concentrate on the application, engineering and sales of finned tube and condenser tube products. He will work with the processing, refining and power fields in Oklahoma, Arkansas and Northern parts of Texas, Louisiana, Mississippi, Alabama and Western Tennessee.

Price

Colonel Bruce Price, recently retired from the Air Force, has joined Fisher Governor Co., Marshalltown, Iowa. He worked with Fisher in 1930's after graduation from Iowa State College, and joined the Air Force in 1938, where he spent many years on assignment in research and development projects. At Fisher, Price will devote attention to the company's export market and to sales engineering of special application projects.

Additon

E. P. Additon has been named manager, contracts and sales promotion, Chemical Plants division, Blaw-Knox Co., Pittsburgh. He was formerly in the division's office, Haddon Heights, N. J., as district sales engineer. Additon will have charge of contract administration, will direct the advertising program and coordinate sales promotion activities. He joined Blaw-Knox in 1942, serving in numerous engineering capacities before being assigned to the New Jersey office.

Clarke

Edwin R. Clarke has been named manager, industrial relations, for American Meter Co., Philadelphia. He joined the firm from Dayton Rubber Co. where he was director of industrial relations. Previously he was industrial relations manager for Goodyear Tire and Rubber Co. He is a member of AMA and the Industrial Relations Association of Philadelphia. After graduating from Harvard University, Clark studied Business and engineering administration at M. I. T.

Howard

Sheldon K. Howard has been named Diesel division manager, Fairbanks, Morse & Co., Chicago. He was previously at Atlanta as manager of the Diesel department for the past eight years. Prior to 1952, Howard was a diesel sales engineer in the Boston territory. He is a graduate of the University of Main where he received his B.S. degree in mechanical engineering in 1939.

Durkin

L. L. Durkin has joined Chiksan Export Co. as senior sales representative. His first assignment, just concluded, was a tour of South America oilfields. Durkin was formerly sales representative with Well Equipment Manufacturing Corp., Houston, a division of Chiksan Co. Beginning with 1950, he eventually served Chiksan-Weco customers in almost every territory in the Mid-Continent. His new duties will involve sales and service on the Chiksan line.

Rhodes

John H. Rhodes has been named director of marketing, Instrument division, Perkin-Elmer Corp. He joined Perkin-Elmer in 1952 as a sales engineer and in 1953 became manager of the Chicago sales office. In 1957 he became sales manager, Instrument division. Rhodes graduated from North Carolina State College and received a M.S. degree in business and engineering administration from M. I. T. He is a member of AMA and ISA.

Broggi

Dante E. Broggi has been named vice president of American Meter Co. He joined the company in 1958, having previously been president and director of Neptune Meter Co. A national director of the Non Ferrous Foundrymen's Association, Broggi also serves on the board of directors for Safety Industries, Hamden, Conn., and for Mid-Century Instrumatics, New York. He graduated from the College of the City of New York.

Jackson

William H. Jackson has been elected vice-president in charge of sales, Diamond Power Specialty Corp. Formerly assistant marketing manager of The Babcock & Wilcox Co.'s Boiler division, he will be responsible for the sales of all Diamond Power products. Jackson will headquarter at the company's Lancaster, Ohio, plant. He joined Babcock & Wilcox in 1936 as a student engineer at the company's Barberton, Ohio, works. When Babcock & Wilcox consolidated division operations in Barberton last year, he was appointed assistant marketing manager for all industrial products.

NEW EMS SERIES
Magnetic,
across-the-line
Motor Starters

INDUSTRIAL CONTROL PYLETS®

EXPLOSION-PROOF AND DUST-TIGHT

FOR HAZARDOUS LOCATIONS

SECOND TO NONE FOR... SAFETY AND ECONOMY... LONG SERVICE LIFE

New ECB Series Circuit Breakers

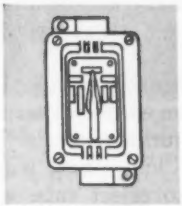
NEW

CORROSION-PROOF COVER JOINT:

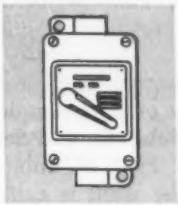
The metal to metal joints of all explosion-proof Pylets, both the ground joint types and the threaded joint types, are cadmium plated to maintain the integrity of the flame arresting path against corrosion. Only cadmium plate can provide this valuable protection on ferrous alloy castings.

The new EMS motor starters, ECM combination motor starters and ECB circuit breakers have cadmium plated, ground cover joints plus the following features:

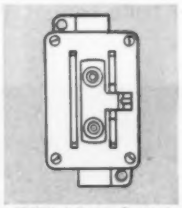
- COMPACT RECTANGULAR SHAPE
- HINGE SUPPORTED COVER
- RAIN-TIGHT PROTECTION
- COMPLETE ACCESSIBILITY FROM FRONT
- MINIMUM BENDING OF CONDUCTORS
- TAPERED TAPPED HUBS



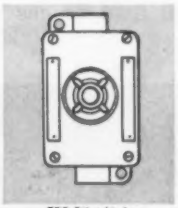
ER-SS Selector Switches



ER-M Manual Motor Starters



ERC Push Button Stations



ERP Pilot Lights

SINCE 1897

Sold Nationally Through Authorized Distributors. Write for Literature.

THE PYLE-NATIONAL COMPANY

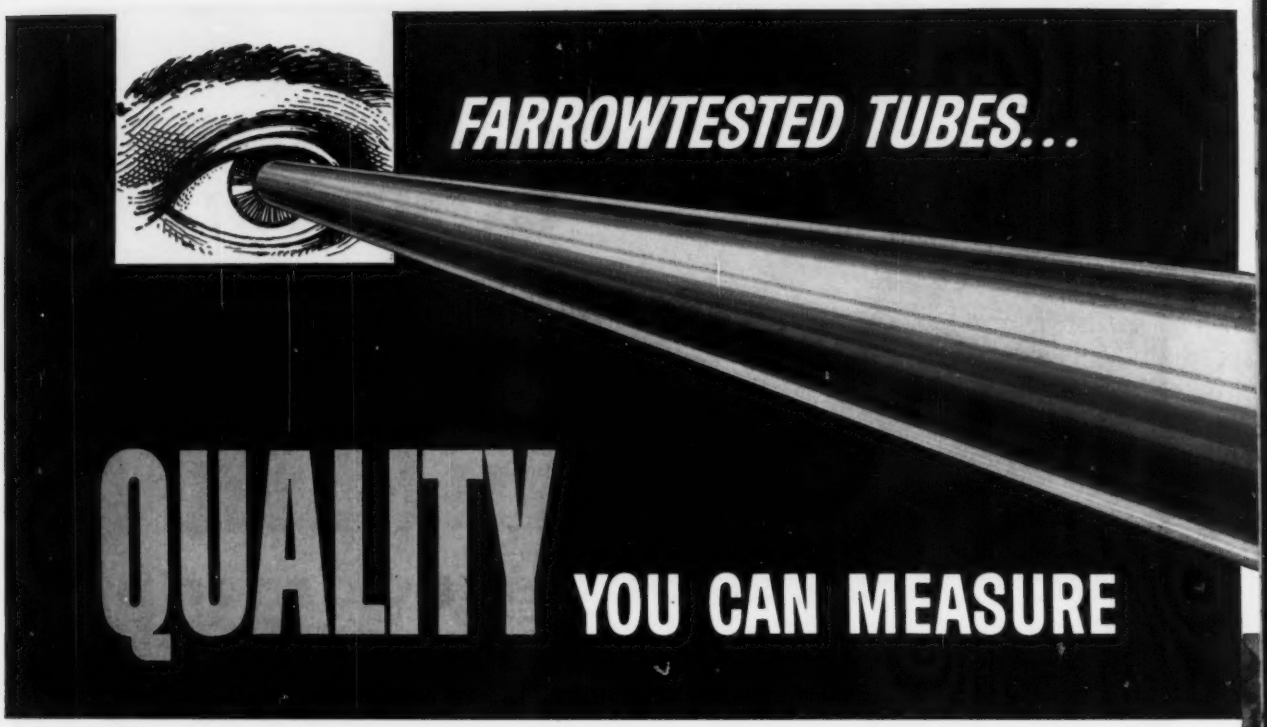
WHERE QUALITY IS TRADITIONAL

1393 North Kostner Avenue, Chicago 51, Illinois

BRANCH OFFICES AND AGENTS IN PRINCIPAL CITIES OF THE U.S. AND CANADA • CANADIAN AGENT: THE HOLDEN CO., LTD. MONTREAL • RAILROAD EXPORT DEPARTMENT: INTERNATIONAL RAILWAY SUPPLY CO., 30 CHURCH ST., NEW YORK 7, N.Y. • INDUSTRIAL EXPORT DEPARTMENT: ROCKE INTERNATIONAL CORP., 13 E. 40TH ST., NEW YORK 16, N.Y.

CONDUIT FITTINGS • PLUGS AND RECEPTACLES • LIGHTING FIXTURES • FLOODLIGHTS

For more data on advertised products, use Readers' Service Cards, last page.



Republic ELECTRUNITE

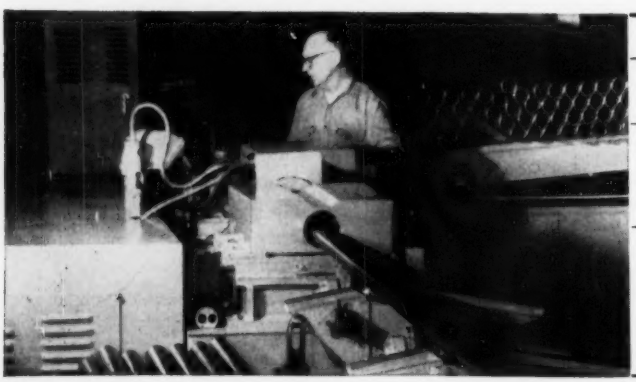
HEAT EXCHANGER TUBING... CARBON AND STAINLESS STEELS

Specify FARROWTESTED Republic ELECTRUNITE® Heat Exchanger Tubing and get predictable, dependable service every time!

FARROWTESTED tubes must pass the most searching test of all, a non-destructive eddy-current test that probes for and detects injurious defects. The "magic eye" of FARROWTEST® looks deep within the tube wall, is calibrated to reject tube with defects as shown in table below. Defects that pass internal fluid or gas pressure tests cannot pass FARROWTEST! This is an exclusive test with Republic.

Quality you can measure! FARROWTEST is offered as an alternative to other less positive tests at no increase in cost. Carbon steels produced to ASTM specification A-214; stainless steels to A-249. Both specifications include eddy-current requirements.

As a tube buyer and user, you owe it to yourself and your company to get ELECTRUNITE and FARROWTEST facts firsthand. Call your Republic representative. Or, use coupon and write direct.

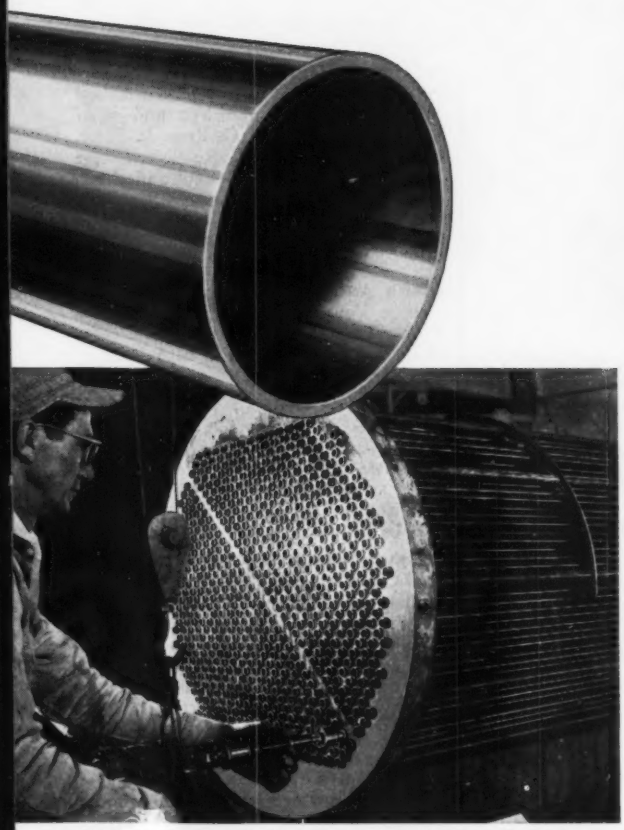


FARROWTEST REJECT TABLE

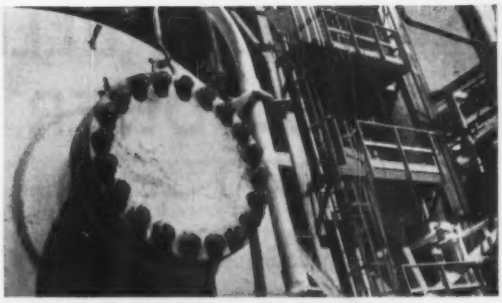
Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.

For more data on advertised products, use Readers' Service Cards, last page.



REPUBLIC ELECTRUNITE STAINLESS STEEL HEAT EXCHANGER TUBING rolls in easy. You get a good tight seal every time. That's why more and more refineries and processing plants are using ELECTRUNITE for original equipment and for retubing operations. Write today.



REPUBLIC ALLOY STEEL STUDS AND HIGH CARBON HEX NUTS provide the strength needed in high pressure equipment. High tensile strength with tough threads offers maximum holding power and resistance to wear. Tighten smoothly, back-off easily. Send coupon today.

SPECIFY REPUBLIC SRK PLASTIC PIPE for a variety of oil and natural gas handling where corrosion is a factor. Republic SRK is lightweight for low-cost shipping and easy handling. It is easy to cut, join, and make a permanent installation fast. Send for literature.

POSITIVE SHIPPING PROTECTION—Republic offers a full range of barrels, drums, and pails in many styles and sizes up to 55 gallons—ENDURO® Stainless Steel, galvanized and tinned steels, open-hearth steel—plain, lacquered, decorated. Send coupon today.

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
DEPT. PR-7855
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send information on the following Republic products:

☐ ELECTRUNITE Heat Exchanger Tubing
☐ Carbon ☐ Stainless
☐ SRK Plastic Pipe ☐ Steel Drums ☐ Shipping Containers
☐ Alloy Steel Studs ☐ High Carbon Hex Nuts

Name_____ Title_____

Company_____

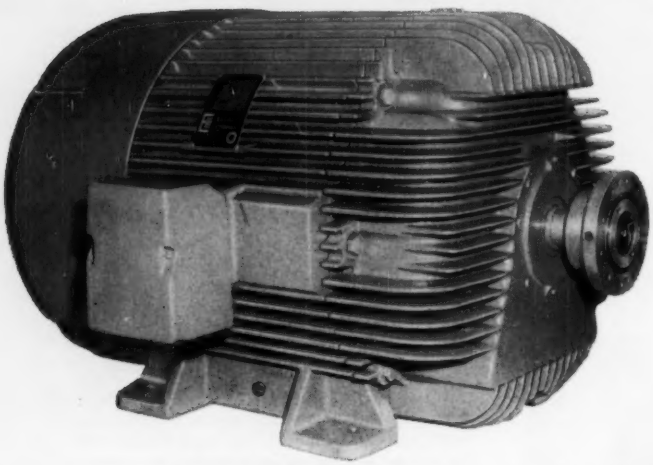
Address_____

City_____ Zone____ State_____

For more data on advertised products, use Readers' Service Cards, last page.

ELLIOTT C-W SEALEDPOWER MOTORS

This new 300-hp unit is the largest of the Elliott C-W "family" of ribbed-frame enclosed motors, pioneered in the United States by Crocker-Wheeler.



BEST FOR YOUR TOUGHEST JOBS BECAUSE THEY ARE BETTER COOLED BETTER PROTECTED BETTER BUILT

IMPORTANT FACTS are given in new Elliott Bulletin PB 6000-2. Send for free copy now.

ELLIOTT Company

Crocker-Wheeler Plant • Jeannette, Pa.

W9-5

Suppliers . . .

MINNEAPOLIS-HONEYWELL REGULATOR CO. has named **Fred Maytag II,** president of Maytag Co., a director. Maytag is also president of Maytag Co., Ltd. and Maytag Dairy Farms, Inc.

CONSOLIDATED ELECTRODYNAMICS CORP. has established a district sales office in Columbus, Ohio, to handle CEC instrumentation in Ohio, Michigan, and Western Ontario.

WESTINGHOUSE ELECTRIC CORP. has named **Mark W. Cresap** president and chief executive officer and **Gwilym A. Price,** chairman of the board. Re-elected were **E. V. Huggins,** vice president and chairman of the executive committee, and **John K. Hodnette,** executive vice president.

SHAND AND JURS CO. has appointed **George Fournier** manager of the New York office. He has been with the company since 1949 in a sales capacity.

AMERICAN CYANAMID CO. has named **Dr. A. G. Hill** manager of its Bound Brook plant. He has been with Cyanamid since 1932 when he joined the company as a research and development chemist.

HOOKER CHEMICAL CORP. has named **Carl I. Gochenour** general manager, product development. Manager of product development, chemicals, since 1957, he will supervise the group handling evaluation and development of all new products coming from centralized research at Hooker's research center, Grand Island, N. Y.

CORNING GLASS WORKS has named **Clark A. Crawford** manager of product planning. He will coordinate development programs with product line divisions and research, development, engineering and market research groups.

COOPER ALLOY CORP., Hillside, N. J., has named **Ramon J. Galvez, Jr.,** supervisor of radiology. He will be responsible for all X-Ray, Zyglo and Gamma Ray inspection of Cooper Products.

CONTINENTAL TUBE CO. has named **Charles E. Williams** vice president. He was active in pipe sales for nine years before coming to Houston in 1945. In 1957, he joined Continental as sales manager.

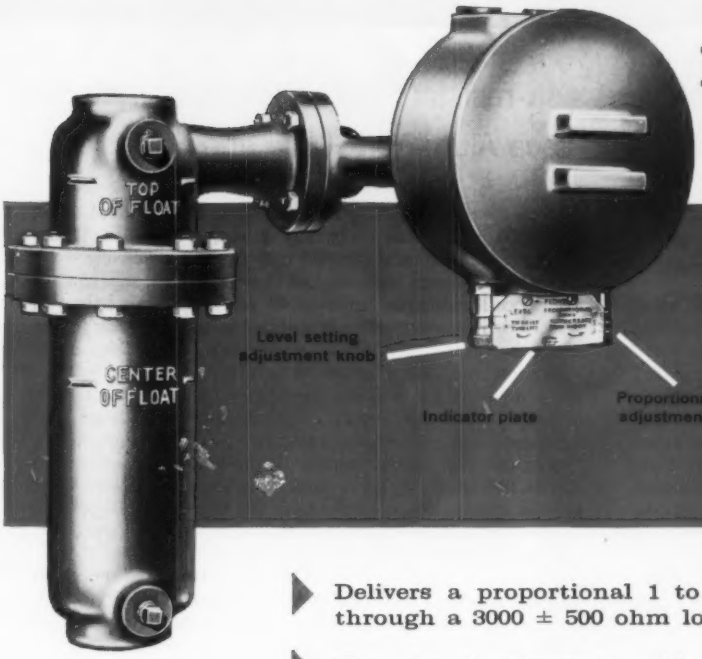
CONSOLIDATED ELECTRODYNAMICS CORP. has granted Van Waters & Rogers, Inc., exclusive right to market two models of CEC's moisture monitors in the 11 Western states and part of Southwest Texas.

WALWORTH CO. has named **John C. Wallace** president and **Harold Brown** vice president and general sales manager.

For more data on advertised products, use Readers' Service Cards, last page.

NOW FISHER LEVEL-TROL®

FOR ELECTRONIC SYSTEMS

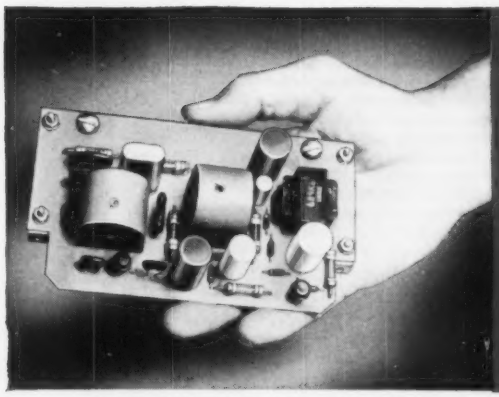


Quick accurate external adjustment

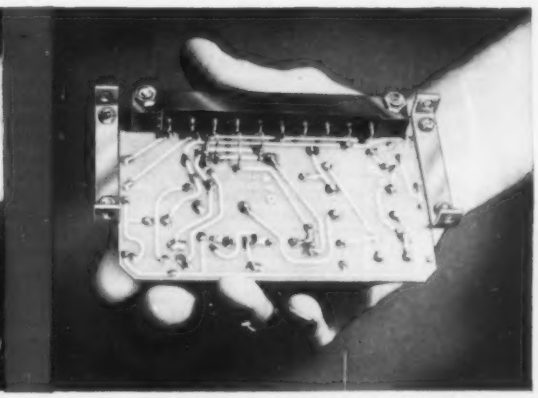
- **Delivers a proportional 1 to 5 milliampere dc signal through a 3000 ± 500 ohm load.**
- **Has plug-in converter with printed circuit. Conventional leads and unnecessary wiring are eliminated.**

This Fisher explosion-proof Electronic Level-Trol features external adjustment for proportional band and liquid level height, and incorporates extreme simplicity of design throughout. Silicon transistors and diodes are used instead of the conventional vacuum tubes. You do not need any additional parts to reverse action of the unit. With only .25% effect from ±15% supply voltage change, line voltage fluctuation is of negligible effect.

Fisher Bulletin F-85 will give you complete details on the Fisher Type 2300 Electronic Level-Trol. Send for it.



Plug-in electronic converter assembly.



Printed circuit of the converter assembly.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

FISHER GOVERNOR COMPANY

Marshalltown, Iowa Woodstock, Ontario London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

FISHER® Controls

SINCE 1880

For more data on advertised products, use Readers' Service Cards, last page.

See why ALCOA ALUMINUM makes a good design habit

Requirement: Low-cost, corrosion-resistant heat exchanger material
Key to Good Design: Specify Alcoa Aluminum Tube and Sheet

If corrosion resistance, long life, product purity and economy are considerations in your heat exchanger application, specify aluminum! ALCOA® Aluminum has been solving such problems for over 40 years.

In the petroleum industry, ALCOA Aluminum Tubes serve in main column overhead condensers where their freedom from fouling and excellent heat transfer properties have made them a natural selection. Heat exchangers made of ALCOA Aluminum Tube and Plate are used in the production of ammonia, nitric acid, vegetable oils, naval stores, naphthalene, hydrogen peroxide, oxygen and urea. These and other processes call for heat exchangers with combinations of high strength, excellent sub-zero physical qualities, high thermal conductivity, or nontoxic and noncatalytic properties. ALCOA Aluminum alloys meet all these requirements.

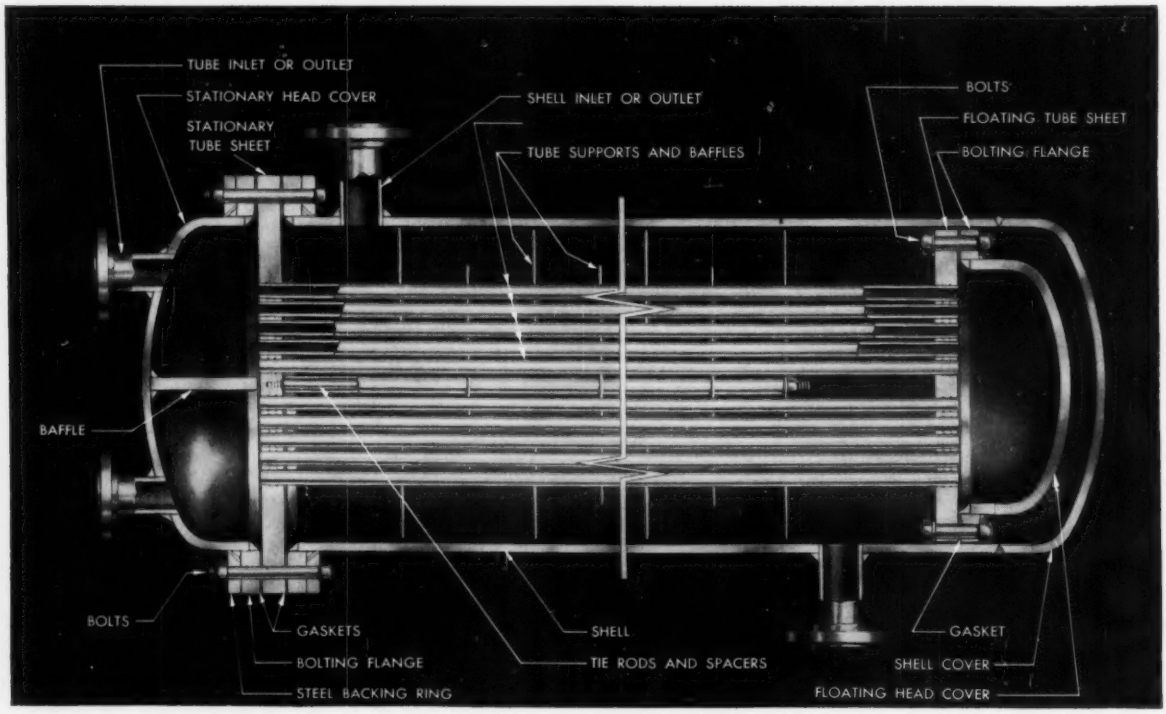
As for cost, ALCOA Aluminum Tube is the most inexpensive. In the common sizes it costs one-third less than mild steel, one-half as much as admiralty, and one-fifth that of stainless.

ALCOA Aluminum alloys are ideally suited to a wide range of maintenance methods. For relatively soft or loose scale, water jets and brushes are usually satisfactory. Wet sandblasting as well as chemical cleaners may be used effectively.

ALCOA engineers have worked closely with all segments of the process industries for over 40 years, and can help you specify the aluminum alloy best suited to your heat exchanger and other process applications. ALCOA's unparalleled experience in this field is available to you for the asking. Write to the address on the coupon, stating your requirements as specifically as possible. ALCOA's development engineers will welcome the opportunity to work with you on your problems.

You can also take advantage of the wide selection of free ALCOA literature on aluminum for heat exchangers and other process applications. Simply check the booklets you want on the coupon and mail to the address indicated. ALCOA will forward your material promptly and without obligation.

ALCOA is conducting a series of engineering conferences on process industries applications of aluminum during 1959 in a number of major cities. Contact your nearest ALCOA sales office for full particulars and dates.

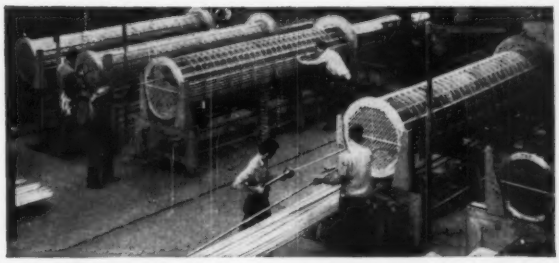


For certain processes where corrosive or sensitive materials are involved, it is often advisable to use aluminum for entire heat exchanger systems to avoid system corrosion and contamination of the product. A typical all-aluminum heat exchanger is shown here. Alloy recommendations are given in the table opposite.

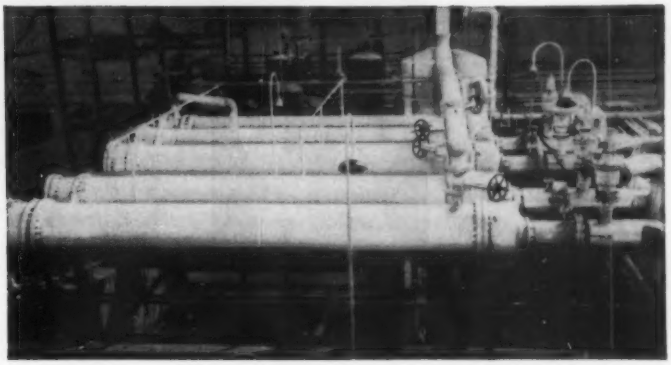
Alcoa Aluminum Tubing protects color in the world's largest rotary steam-tube drier. The drier measures 10 ft in diameter by 100 ft long.

A Midwest utility saved 50 per cent on tubing costs by using Alcoa Aluminum instead of admiralty for tubing in this surface condenser. Successful operation of this unit has led to the installation of similar units by other utilities. This use demonstrates aluminum's economy and superior resistance to ammonia, carbon dioxide and hydrogen sulfide.

A battery of all-aluminum heat exchangers in a polyethylene plant. Selected for initial low cost, these aluminum exchangers provide freedom from product contamination as well as desirable low temperature properties.



Construction of a heat exchanger utilizing Alcoa Aluminum Tube. Superior working properties plus the cold-drawing method by which Alcoa seamless heat exchanger tubes are produced results in close dimensional tolerances and smooth inside and outside surfaces.



This all-aluminum dephlegmator in a large coke plant is used for the regeneration of ammonia liquor in a hydrogen sulfide scrubbing operation. Aluminum tubes lasted five times longer than steel tubes in a similar use.

Alloy Recommendations for Aluminum Heat Exchanger Construction

	Alcoa Designation	ASTM Specification*	Alloy
Tubes	3003-H14	B234	M1A
Alclad (inside)	3003-H14	B234	clad M1A
Alclad (outside)	3003-H14		clad M1A
Alclad (both sides)	3003-H14		clad M1A
	6061-T6	B234	GS11A
	6062-T6	B234	GS11C
Tube Sheets	3004-H112	B178	MG11A
Alclad	3004-H112	B178	clad MG11A
	6061-T6	B178	GS11A
Alclad	6061-T6	B178	clad GS11A
Baffles	3003-H14	B178	M1A
Alclad	3003-H14	B178	clad M1A
Tie Rods	6061-T6	B273	GS11A
Shells & Headers	3003-H112	B178	M1A
Alclad	3003-H112	B178	clad M1A
	3004-H112	B178	MG11A
	5052-H112	B178	GR20A
	5154-H112	B178	GR40A
Fittings	3003-F	B274	M1A as applicable
	6061-T6	B274	GS11A as applicable
Flanges	6061-T6	B247	GS11A as applicable

*Only the basic number is shown since Alcoa products are manufactured to the latest issue of the specification. The complete number would indicate the year of issue.

ALCOA ALUMINUM
ALUMINUM COMPANY OF AMERICA

For exciting drama watch "ALCOA THEATRE," alternate Mondays, NBC-TV, and "ALCOA PRESENTS," every Tuesday, ABC-TV

Aluminum Company of America
874-E Alcoa Building, Pittsburgh 19, Pa.

Please send me the following literature covering Alcoa Aluminum in heat exchanger and other applications in the process industries.

- ☐ 10186 Alcoa Aluminum Heat Exchanger Tubes
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 20272 Aluminum Alloys for Handling High Purity Water
- ☐ 20268 Resistance of Aluminum Alloys to Fresh Waters
- ☐ 20935 Designing to Prevent Corrosion

Name_____

Company_____

Title_____

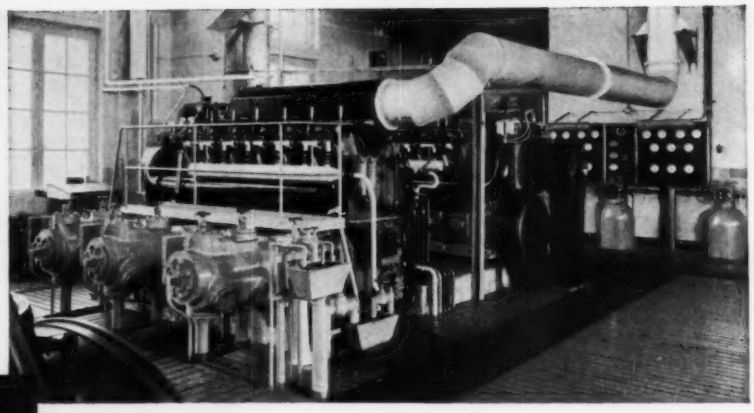
Address_____

City_____

State_____

553/5e

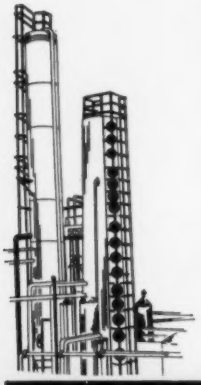
DEPENDABLE AND ECONOMIC OPERATION



– an essential requirement for gas engine driven compressors which have to render continuous service in petroleum refineries, oil fields, long-distance gas transport and underground gas storage. In this respect you can fully rely on the Meer type, in stationary and skid-mounted design with fan cooling. The compressor part of the unit is designed to suit your specific demands. Our programme includes a variety of models with ratings of from 200 to 2,500 HP. For similar purposes we also manufacture piston compressors in opposed arrangement or vertical design for electric drive up to the highest pressures and rates of performance.

MANNESMANN-MEER

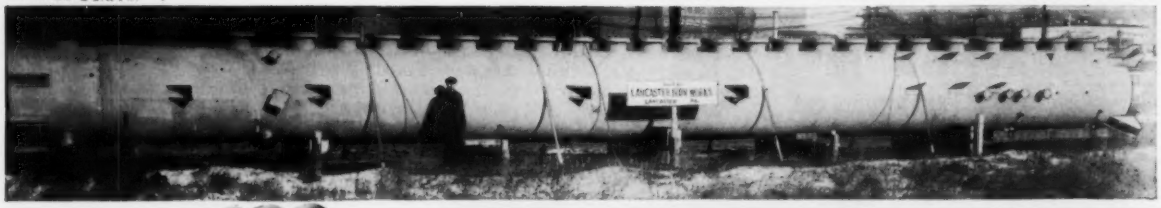
MÖNCHENGLADBACH · GERMANY · TELEX 0852 852

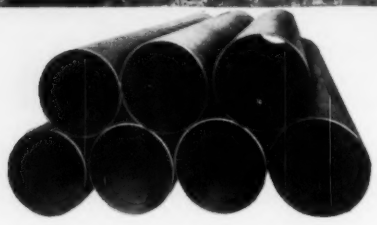


STEEL PLATE FABRICATION

For The Petroleum Industry

Our experience in fabricating towers, storage tanks, pressure vessels, steel and wrought iron pipe and piling dates back almost a half-century. Coupled with modern engineering and production equipment and facilities, this experience makes Posey Iron a recognized source for these and other petroleum industry requirements. Write without obligation for complete information about our experience, facilities and installations in your industry.





POSEY IRON WORKS, INC.

LANCASTER, PENNSYLVANIA

New York Office: Graybar Building

DIVISIONS: Steel Plate Fabrications ● Brick Machinery and Mixers ● Industrial Heating ● Iroquois Asphalt Plant ● Gray Iron and Steel Foundry ● Tunnel and Mine Equipment

Suppliers . . .

Fred W. Belz, formerly company president, will be chairman of the board, and **David R. Pokross** will be chairman of the executive committee. All are longtime Walworth executives.

GRAVER TANK & MANUFACTURING CO. has named **William H. Dwyer, Jr.,** manager of Mid-Continent and Gulf Coast sales, specializing in oil and gas equipment. He was previously manager of Gulf Coast sales.

BECKMAN INSTRUMENTS, INC.'S Scientific and Process Instruments division has formed the Custom Products department and named **Stanford B. Spracklen** manager. He was previously associate manager of engineering for the division.

KEASBEY & MATTISON CO., Ambler, Pa., has named **Vernon F. Stompler** inspection control supervisor in the Quality Control division. He was formerly manager of pressure pipe sales.

ATLAS POWDER CO. has named **William R. Lucas** manager of its regional chemicals sales office in Chicago and **Edward M. Simon, Jr.,** as assistant manager of the New York regional chemicals sales office.

PRECISION SCIENTIFIC CO. has appointed as district managers, **James F. Ramseth,** Chicago; **Robert G. Mullins,** Houston; **Wallace H. Dickson,** Bala-Cynwyd, Penn., and **Melvin M. Swartz,** San Francisco.

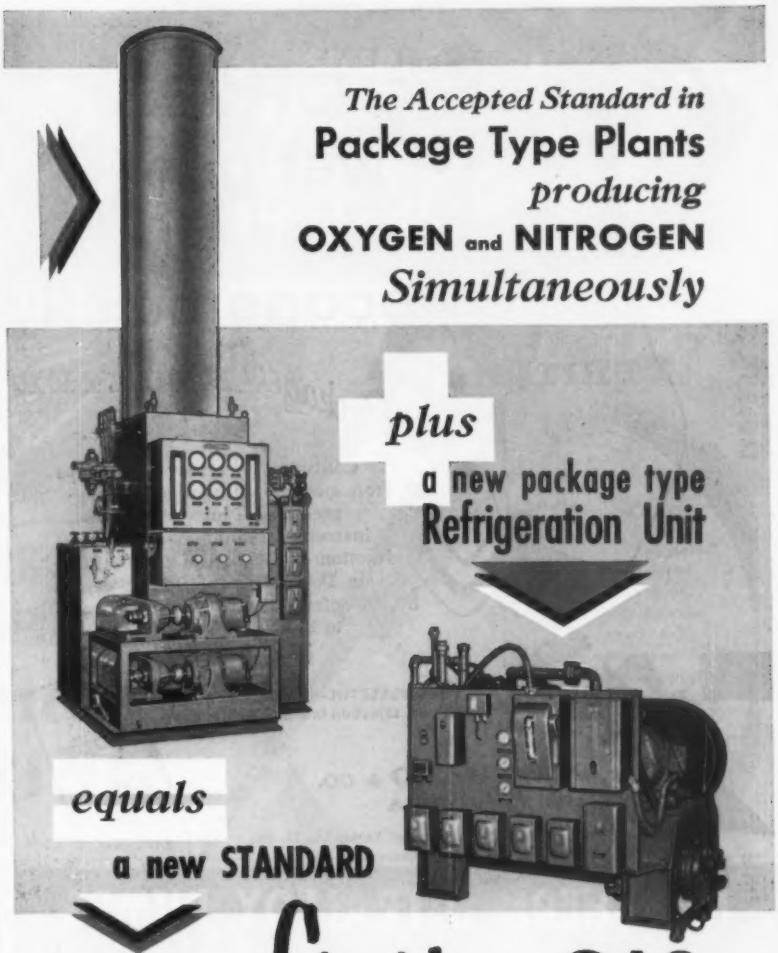
GENERAL ELECTRIC CORP.'S Computer department, Phoenix, has appointed **Dr. G. E. Adams** and **R. J. Noorda** operations analysts. Both men have been with the company several years.

WAIN-ROY CORP.'S Sales and Service departments have moved to 150 River St., Fitchburg, Mass. The Order and Distribution department also made the move.

VISCO PRODUCTS CO., Houston, has named **Charles F. Spangler** management consultant and **David M. Jacks** vice presi-

Use Readers' Service Postcard for More Information on Advertised Products

The Accepted Standard in
Package Type Plants
producing
OXYGEN and NITROGEN
Simultaneously



plus
a new package type
Refrigeration Unit

equals
a new STANDARD

now *Liquid* or GAS
OXYGEN and NITROGEN
simultaneously

FLEXIBILITY of operation, providing ANY COMBINATION of products, liquid or high pressure gas PLUS simultaneous production of BOTH oxygen and nitrogen delivers maximum yield of combined products at minimum cost of operation with little operator's attention. Packaged design requires minimum of installation cost and space.

This most modern and efficient design from Independent combines the best features of the earlier two-product package plants pioneered by Independent with the latest concepts of external refrigeration. Type illustrated in 1500 to 5500 cu. ft. per hour capacities. Other types in larger and smaller sizes. Pure argon available on larger sizes.

We invite your Inquiry

INDEPENDENT ENGINEERING COMPANY, Inc.
Manufacturers of
CONSULTING IECO DESIGNING RESEARCH
CYLINDERS AND GAS PRODUCING EQUIPMENT
ACETYLENE · OXYGEN · NITROGEN · ARGON
O'FALLON 6, ILLINOIS

For more data on advertised products, use Readers' Service Cards, last page.

DRIES wet gas or air economically

PRITCHARD *Packaged* HYDRYER

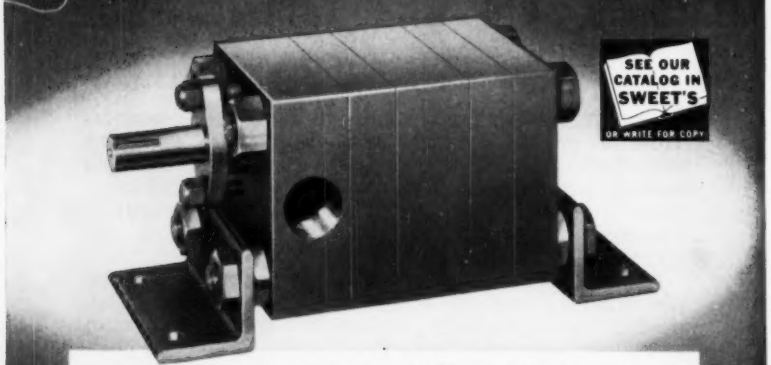
Continuously removes moisture from gas or air stream at full line pressures. Protects processes, instruments, equipment at a fraction of the cost of field-built dryers. Dew points to -100°F. Sizes to 50,000 scfm. Saturated temperatures to 120°F. Pressures from 30 to 3500 psig.

FREE BULLETIN—Gives application details, selection tables. Write for copy.

J. F. PRITCHARD & CO.
OF CALIFORNIA
Dept. 120, 4625 Roanoke Parkway, Kansas City 12, Mo.

NORTHERN NITRALLOY PUMPS

Lube oil, seal oil and fuel oil pumps for compressors and engines



Complete range in pump sizes from ¼ GPM to 146 GPM. Pressures to 2000 PSI. Proven in thousands of installations and backed by 50 years of engineering and production experience, Northern Steel Block Nitralloy Rotary Gear Pumps are unexcelled for precision manufacture, accurate assembly and dependable, long life operation. Write for free catalog and engineering data.

NORTHERN ORDNANCE, INCORPORATED
Subsidiary
NORTHERN PUMP COMPANY
MINNEAPOLIS 21, MINN.

Suppliers . . .

dent and general manager. The National Aluminate Corp. subsidiary also named **Paul E. Southern** manager, administrative services.

U. S. RUBBER CO. has appointed Chicago-Wilcox Manufacturing Co., Chicago, servicing distributor for its packings. The appointment covers all packings in the U. S. line.

GENERAL ELECTRIC CO. is combining its Communication Products department at Lynchburg, Va., with the Technical Products department, Syracuse, N. Y. **Harrison Van Aken** will head the operation from Lynchburg headquarters.

U. S. RUBBER CO.'S Naugatuck Chemical division has named **Dr. Travis W. Brasfield** Kralastic commodity sales manager. A University of Arkansas graduate, he has M.S. and Ph.D. degrees from the State University of Iowa.

KEASBEY & MATTISON CO., Ambler, Pa., has named **Michel Gochtovtt** design manager, Central Engineering department. Holder of a mechanical engineering degree from the University of Paris, he was formerly with Renault Automobile Co.

BLAW-KNOX CO.'S Buflovak Equipment division has named **D. B. Gooch Associates, Inc.,** district sales representative, Birmingham, Ala., with offices at 5018 First Ave., N.

OAKITE PRODUCTS, INC., recently held its 50th Anniversary Sales Conference in New York. Attending were 45 of the firm's technical service representatives from New England, and New York divisions. The conference is third in five such regional meetings.

PETRO-CHEM DEVELOPMENT CO., INC., has delegated its Canadian subsidiary, Petrochem Isoflow Furnaces, Ltd., to handle all sales and services of Isoflow furnaces in Canada.

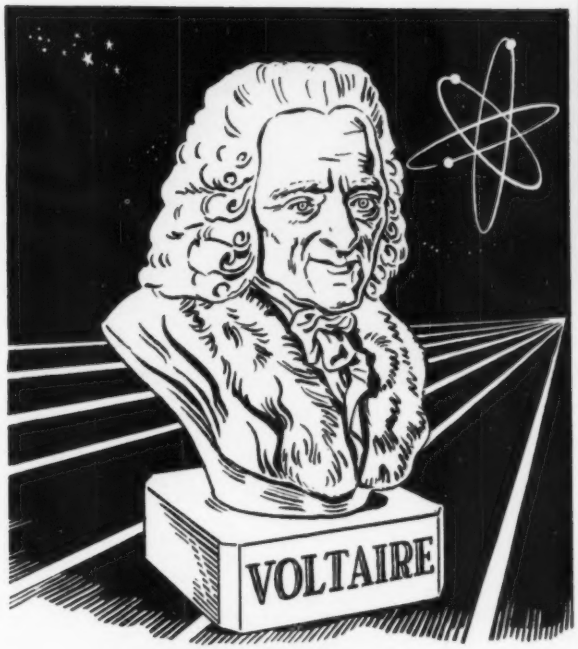
TRETOLITE CO.'S Northwestern division, Great Bends, Kan., has named **Grady P. Bolding, Jr.,** assistant manager. With Tretolite four years, he transferred to Great Bend from Magnolia, Ark., in mid-1957.

JEFFERSON CHEMICAL CO. has named **Leroy Whitaker** market development man at its Commercial Development division. He has been a senior research chemist at Jefferson's Austin, Texas, laboratories since 1957.

U. S. STEEL CORP.'S Oil Well Supply division has named **Charles V. Black** store manager, Abilene, Texas. He has been with the company since July, 1946, in various sales and managerial positions.

THE SWARTWOUT CO.'S Ventilation division, Cleveland, has named **Robert Parshall** sales manager. He returned to

For more data on advertised products, use Readers' Service Cards, last page.



IDEAS and ENGINEERING

The philosopher, Voltaire, said that a hundred men each with an idea are worth more than one man with a hundred ideas. In its management and staff, The C. W. Nofsinger Company has *both* individual thinkers and group ideas, to serve its clients best. Over the years, we have provided complete engineering services to many widely-known refiners and chemical manufacturers throughout the United States and Canada. We shall welcome your inquiries on the following *typical* services:

- **Consultation**
- **Economic Analysis**
- **Modernization Surveys**
- **Process Development and Design**
- **Mechanical Design**
- **Procurement and Expediting**
- **Construction and Supervision**
- **Start-Up and Operating Assistance**

Catalytic and Thermal Processing
Gas and Gasoline Processing
Grease and Oil Compounding
Petrochemicals

In Engineering it's the People that Count

THE C. W. NOFSINGER CO.

Engineers and Contractors for the Petroleum and Chemical Industries
307 East 63rd Street Kansas City 13, Missouri

Representatives
WEST COAST–A. R. Chandler, 609 S. Grand Ave., Los Angeles 17, Calif.
GULF COAST–Russell G. Dressler, 204 Carolwood Dr., San Antonio 13, Tex.

So SIMPLE that "Specials" are Likely to be Standard!

A sleeve, raised and lowered within a non-magnetic tube, attracts or releases an Alnico magnet attached to a mercury switch. Basically, this is Magnetrol

MAGNETROL

The World's Most Dependable

LIQUID LEVEL CONTROL

Because of the utter simplicity of Magnetrol's magnetic operating principle, standard models can be easily adapted to meet any special requirements for pressure, temperature or corrosive liquids . . . and usually at little extra cost. This Magnetrol versatility has solved all kinds of tough level control problems . . . and given our engineers wide application experience that can be invaluable to you.

Magnetrol is so simple that failure is all but impossible! Using only permanent, unfailing magnetic force for its operation, there's nothing to wear out . . . no diaphragms or bellows to stiffen and rupture . . . no electrodes to short or corrode . . . no packing to bind or leak. Magnetrol is practically maintenance-free! Magnetrol units are available for controlling level changes from .0025-in. to 150-ft. . . . with multi-stage switching when desired. Send coupon for full details.

MAGNETROL, Inc.

Send Coupon For Full Details

MAGNETROL, Inc., 2112 **S. Marshall Blvd., Chicago 23, Illinois**

Please send me catalog data and full information on Magnetrol Liquid Level Controls. 6

Name_____

Company_____

Address_____

City_____ Zone____ State_____

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

Swartwout as assistant sales manager in June, 1958, after serving four years as sales manager and vice president of another ventilator company.

COOPER ALLOY CORP. has named **Leslie F. Schurck** director of industrial engineering, Hillside, N. J. He will be responsible for development of wage incentives, plant layout, methods and procedures.

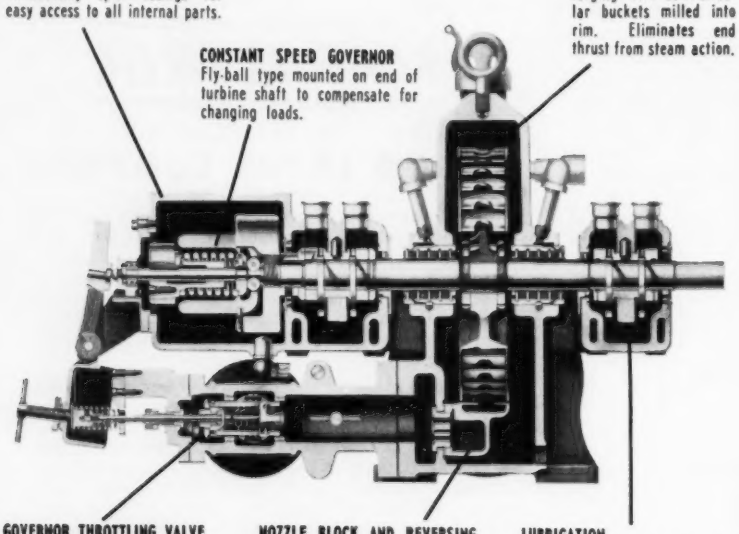
DAYSTROM, INC. has formed Daystrom-Weston Sales division. **William H. Steinkamp** will be director and vice president, marketing.

The first in a series of customer education seminars was held by Crane Packing Co. during the 5-day period, February 16-20. Held at the home offices, Morton Grove, Ill., attendance included 32 plant, engineering, operation and maintenance supervisors from 24 chemical and petroleum companies in various sections of the country. In addition to talks by Crane engineers, the meeting included exchange-of-idea discussions and product demonstrations. The company plans more seminars this year, and will hold them thereafter on a set annual basis, each to be devoted to a different segment of industry.

Whiton

PRECISION ENGINEERED STEAM TURBINES

For almost 50 years, Whiton has combined experience, workmanship and **precision engineering** in building high quality, reliable steam turbines for all types of power and drive applications. Whiton horizontal, helical-flow, single stage turbines are available in 8 wheel sizes. Axial-flow, Curtis-blade turbines are also available. Write for complete data on Whiton's horizontal and vertical turbines.


CASING
Horizontally split casings for easy access to all internal parts.
CONSTANT SPEED GOVERNOR
Fly-ball type mounted on end of turbine shaft to compensate for changing loads.
ROTOR
Solid, one-piece, steel forging with semi-circular buckets milled into rim. Eliminates end thrust from steam action.
GOVERNOR THROTTLING VALVE
Double-seated, balanced V-ported. Admits steam to assure stability control as load varies.
NOZZLE BLOCK AND REVERSING CHAMBER
One-piece unit. 2, 3, or 4 redirecting buckets as required for maximum efficiency.
LUBRICATION
Water cooled oil ring lubrication.

Whiton SINCE 1856

MAXIMUM OPERATING SPECIFICATIONS

POWER	to 1200 HP
SPEED	to 8500 RPM
STEAM PRESSURE	to 1250 PSIG
STEAM TEMPERATURE	to 1050° FTT

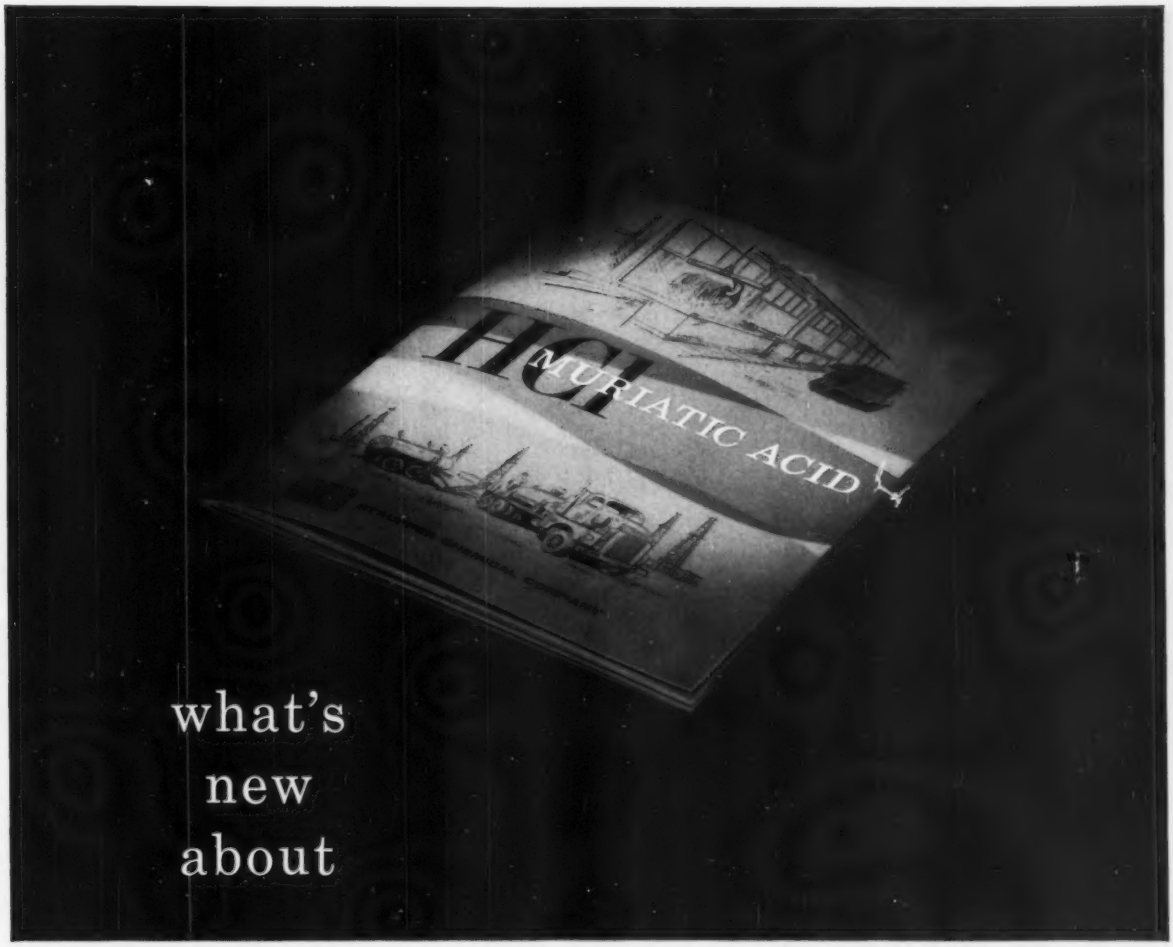
THE WHITON MACHINE COMPANY
NEW LONDON, CONNECTICUT

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd Federal and Dearborn Streets, Chicago 16, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the registry.

Cyclobutane
5.5-Dimethylcyclopentadiene
Tetradecylmethyl ketone
1-Methylcyclobutene
1,1,1-Trichloro-2-propanol (Isopral)
p-Nitrobenzenediazonium p-toluene sulfonate
Propane-1,3-dithiol-2-carboxylic acid Chloramide
N,N'-Dimethyl-decahydro-2-naphthylamine
Perchlorocyclohexane
Perchlorocyclohexene
2,2'-Thiobis(4-chloro-6-methyl phenol)
N-(2-Naphthyl) phosphoramidic acid
Hexadecylmethyl ketone
3-Hydroxy-4-methoxycinnamic acid (Isoferulic acid)
2-Isocyanatopropane
β,β,β-Trichloroborazole
2,3'-Bipyridine
Pentachlorocyclopentadiene
3',3",5',5"-Tetrabromophenolphthalein ethyl ester, potassium salt

For more data on advertised products, use Readers' Service Cards, last page.



MURIATIC ACID?

To be candid... there's nothing new about the acid but there's this new and singularly complete Stauffer brochure. Pages, 44... Tables, 15... Graphs, 9... Illustrations, 24... and many pages of informative text on the major uses of Muriatic Acid.

Now ready for mailing and every consumer should have a copy. Write to either of the addresses below.

Stauffer CHEMICALS SINCE 1885

CONSOLIDATED CHEMICAL INDUSTRIES

Division of Stauffer Chemical Company
Suite 300 South, 6910 Fannin Street
Houston 25, Texas

STAUFFER CHEMICAL COMPANY • 380 MADISON AVENUE • NEW YORK 17, NEW YORK

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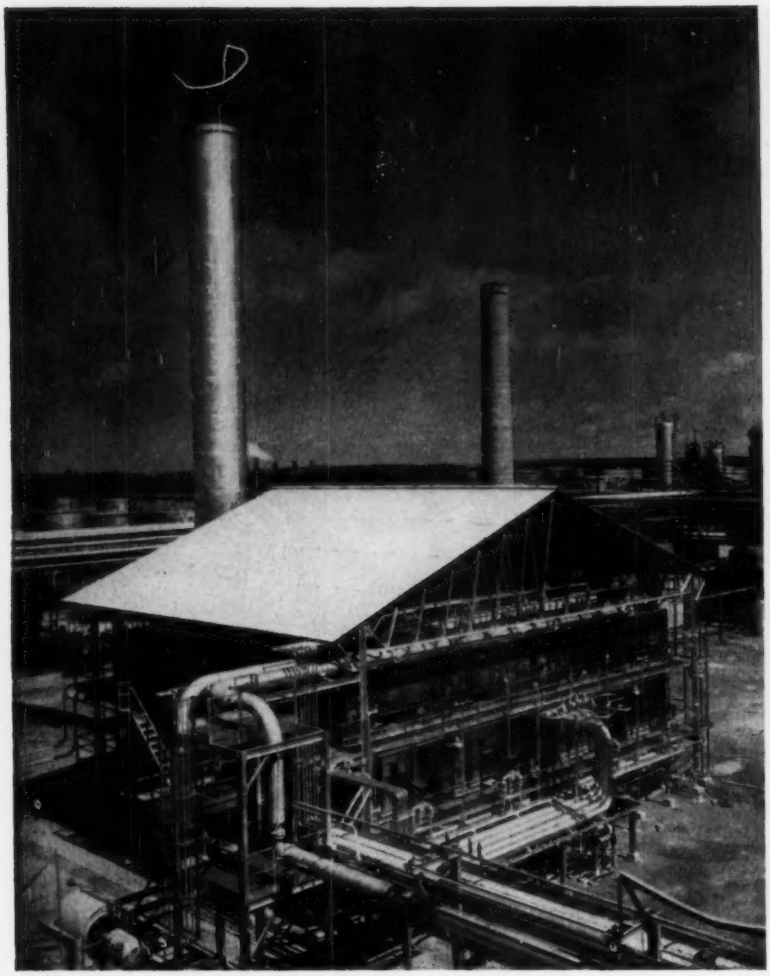
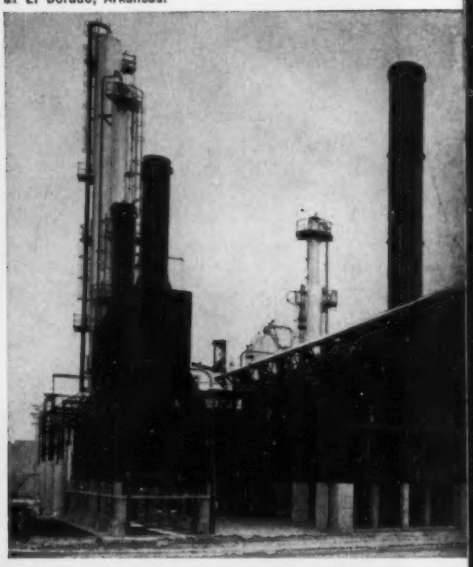
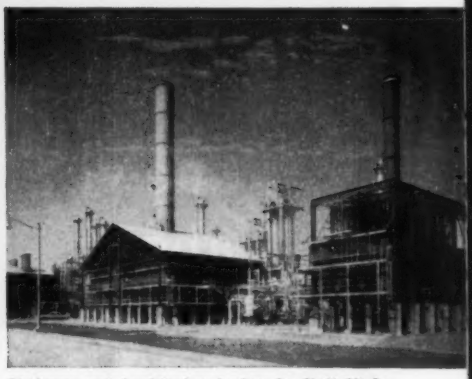


Portable crude heater for Magnolia Petroleum Company, Beaumont, Texas.

Ultraformer heater for American Oil Co. at El Dorado, Arkansas.





Platformer and desulphurizer heaters for Shell Oil Co. at Deer Park, Houston, Texas.

HIGHER EFFICIENCY, LUMMUS OIL HEATERS

Lummus designs horizontal and vertical-tube oil heaters to any size, for any process—anywhere in the world

Major refiners confidently turn to Lummus on their important and difficult oil heater jobs.

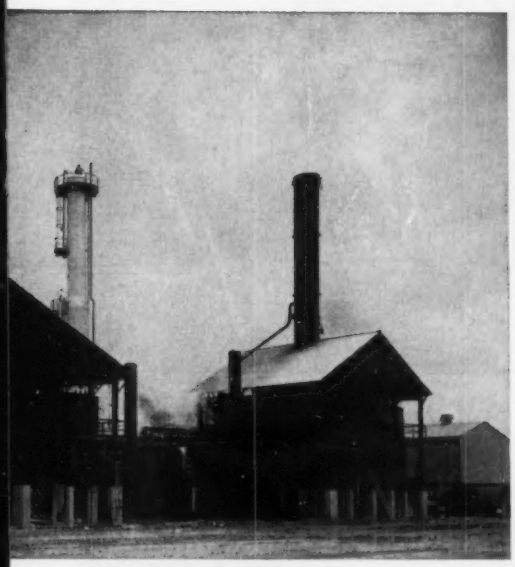
In the last 25 years, the combined capacity of all Lummus oil heaters built has exceeded that of any other company in the world. The reasons: greater durability, more efficient operation, an absolute minimum of days lost to downtime.

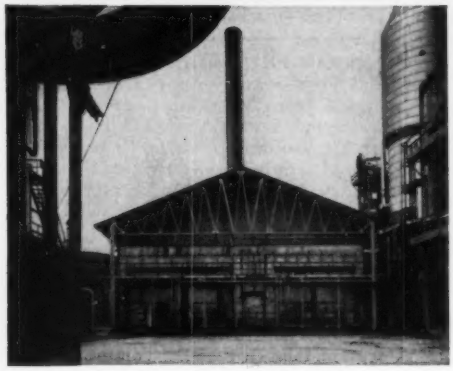
Major refiners maintain large engineering and economics staffs who can evaluate the performance of important heating equipment. They buy more Lummus oil heaters because they *know* through statistical comparison that Lummus gives them *more heater per dollar.*

Lummus offers over a quarter of a century of oil heater experience for petroleum refineries, chemical and petrochemical plants. The highly trained engineering staff of the Oil Heater Division is ready in the Lummus New York office to give each job the full benefit of its accumulated know-how in this field.

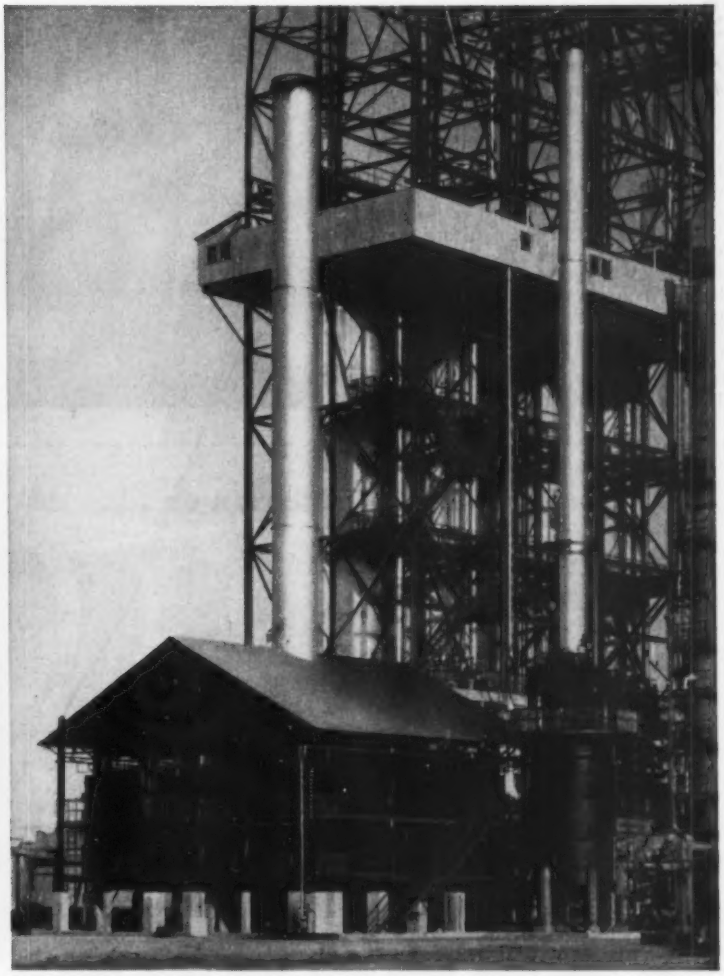
Lummus oil heaters, of both special and standard design, range from 100,000 to 300,000,000 Btu per hour. As illustrated above, neither size, type nor location of the unit presents a problem to Lummus. Because Lummus offers *every* type of oil heater, you can be sure that we will recommend the *right*

For more data on advertised products, use Readers' Service Cards, last page.





Crude heater for Socony Mobil at Paulsboro, N. J.



Delayed coker heater for the American Oil Co. at Yorktown, Virginia.

MINIMUM DOWNTIME MAKE PREFERRED AMONG MAJOR REFINERS

unit for your needs. Complete Lummus facilities are available world-wide through any of the five international Lummus companies. Equipment is designed in New York, procurement is made through the nearest Lummus international office, and the cost of the job is payable in the currency of the country in which the procurement is handled!

Consult with Lummus on your next oil heater – large or small.

Visit the Lummus Exhibit—Fifth World Petroleum Congress Exposition, the New York Coliseum, June 1-5, 1959

LUMMUS

THE LUMMUS COMPANY, OIL HEATER DIVISION
385 MADISON AVENUE, NEW YORK 17, N. Y.

WASHINGTON, D. C. • HOUSTON • MONTREAL • MARACAIBO • LONDON • PARIS • THE HAGUE

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

AMERICAN VISCOSE CORP. has transferred **Nicholas E. Carr, John Adrian, Donald Fiedler, Robert Ridgway** and **Ralph M. Winters, Jr.,** to AviSun Corp. Carr has been named manager of manufacturing, film and fiber. A graduate of M.I.T. with a M.S. degree in chemical engineering practice, he joined American Viscose in 1940 as technical assistant to the plant manager at the Marcus Hook, Pa., rayon manufacturing plant. Adrian has been named sales manager, films. A graduate of Lehigh University, with a B.S. degree in business administration, he came with American Viscose as a salesman in the film division in June 1946 after four years military service.

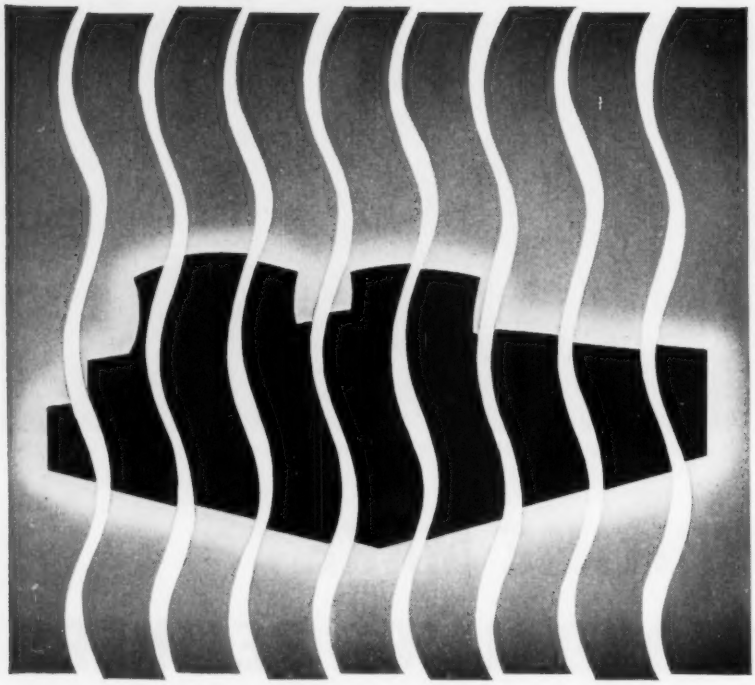
Executives of The Ohio Injector Co. and Jones & Laughlin Supply Division meet to discuss the new distribution agreement for OIC valves to be sold through J&L Supply. From left to right they are W. L. Wolfe, vice president—sales, J&L; Rainey Elliott, president J&L; Roger E. Bremer, executive vice president OIC and G. R. Winder, vice president—marketing, OIC.

BECKMAN INSTRUMENTS, INC.'s Scientific and Process Instruments division has named **John M. Manypenny** assistant marketing manager, responsible for directing national scientific instrument sales. **Joseph P. Addonizio,** manager, Eastern region, will direct all division field operations from Eastern regional headquarters, Mountainside, N. J. He will be assisted by **George Green,** promoted from Western district manager, process instruments, to sales manager, Eastern region, in directing all field sales activities at offices in Buffalo, Mountainside, Washington, D. C., and Toronto, covering the Eastern seaboard and Eastern Canada. **Robert A. Piper,** manager, Midwestern region, will coordinate activities for scientific and process instruments from Midwest regional headquarters, Chicago. He will be assisted by **Jack Challacombe,** promoted to sales manager, Midwestern region, in directing field sales activities at offices in Chicago, Cincinnati, Cleveland, and Houston. **Paul E. Paules,** sales manager, Western region, will direct sales activities for offices in Los Angeles and San Francisco. He will be located at division headquarters in Fullerton, Calif.

BECKMAN INSTRUMENTS, INC. has appointed **H. P. Guertin** sales order manager for the Scientific and Process Instruments division. Formerly with V & E Manufacturing Co., he holds a B.S. degree in mechanical engineering and a M.B.A. degree.

MANNING, MAXWELL & MOORE, INC. has named **John F. Reed** and **Arland R. Walkley** vice presidents. Reed, who is general manager of the Consolidated Ashcroft Hancock division, joined the company in 1944 as planning engineer. Walkley, a graduate of the University of Michigan in mechanical engineering, is now general manager of the Shaw-Box Crane & Hoist division.

Put Darlington insulation on . . .



. . . wherever waste heat comes off

In atomic power stations and oil refineries, in ships and schools and sealing wax plants, Darlington Insulation is cutting heat losses, reducing fuel consumption and saving money for industrial and commercial firms of all kinds.

With Darlington Insulation you can reduce your heat losses by up to 90%—and that means big savings on your fuel bill. Whatever your heat waste problem, there is a Darlington insulating material that can solve it. Why not ask our Technical Division for advice and assistance ? Simply write to :

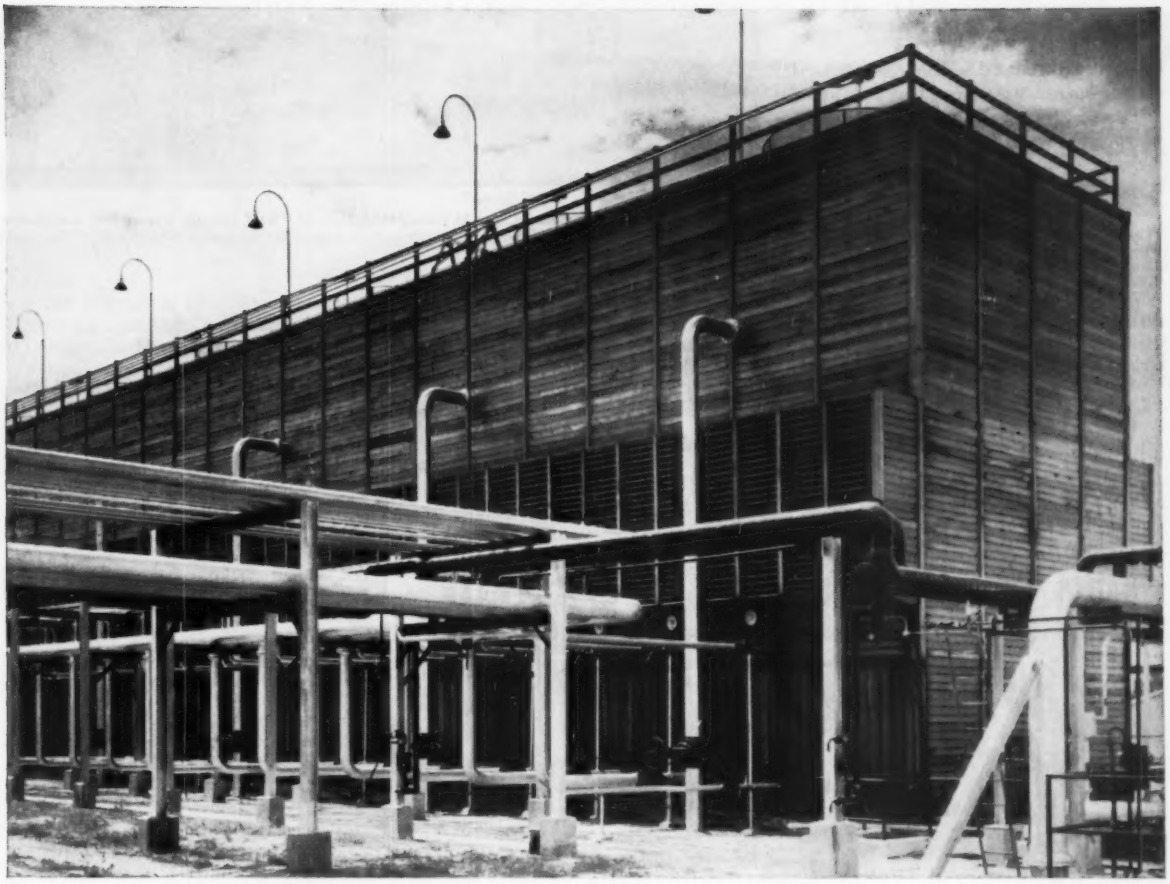
THE CHEMICAL & INSULATING CO. LTD.

Darlington, Co. Durham

or telephone Darlington 3547

THE CHEMICAL & INSULATING CO. LTD. IS A MEMBER OF THE DARLINGTON GROUP OF COMPANIES

MH7



CHROMATE COMPOUNDS STOP CORROSION *before it starts!*

Long before the first drop of water contacts metal in any large recirculating water system, steps should be taken to prevent corrosion.

Early in the design stage, plan on adding a chromate inhibiting compound to recirculating water—from the moment operation starts. That way, clean metal stays clean. Chromate inhibiting compounds will also arrest corrosion in older systems that have been operating without protection, even where rust and scale make it more difficult for inhibitors to reach and protect the metal.

Chromates work two ways: they make waters non-corrosive while making metal surfaces corrosion-resistant. Chromate inhibiting compounds are easy and inexpensive to use. Since conditions and equipment vary, a variety of compounds are available to meet individual requirements.

For the names of manufacturers of corrosion inhibiting compounds containing Mutual Chromium Chemicals, or information on Mutual Chromium Chemicals, mail the coupon below.

Mutual® Chromium Chemicals

Sodium Bichromate
Sodium Chromate
Chromic Acid
Potassium Bichromate
Potassium Chromate
Ammonium Bichromate
Koreon (one-bath chrome tan)

Allied Chemical

SOLVAY PROCESS DIVISION
61 Broadway, New York 6, N. Y.

MUTUAL Chromium Chemicals are available through dealers and SOLVAY branch offices located in major centers from coast to coast.

MUTUAL CHROMIUM CHEMICALS
SOLVAY PROCESS DIVISION
Allied Chemical Corporation
61 Broadway, New York 6, N. Y.

Please send:

☐ List of manufacturers of corrosion inhibiting compounds.
☐ Booklet "Mutual Chromium Chemicals."

Name_____ Position_____

Company_____

Street_____

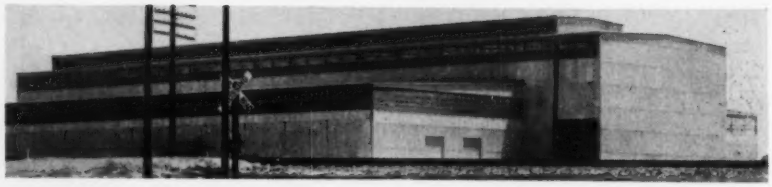
City_____ Zone____ State_____

23-59

For more data on advertised products, use Readers' Service Cards, last page.

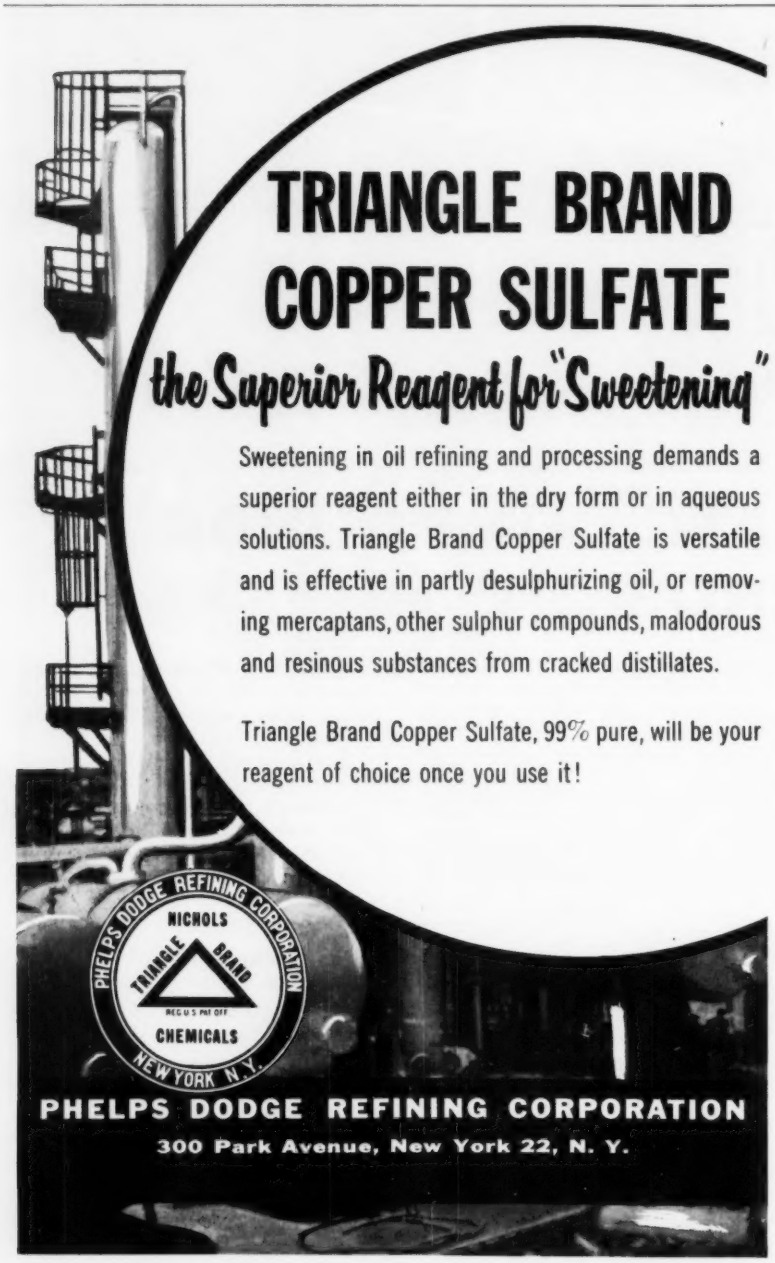
Suppliers . . .

GENERAL ELECTRIC CO.'s Computer department, Phoenix, has named **Guy E. Warner** sales manager of process computers. Warner joined GE in 1947 after receiving electrical engineering and business administration degrees from Kansas State College in 1946 and 1947 respectively. Warner is a member of AIEE, and in 1958 was chairman of the Arizona section, Computer committee.



Grove Valve and Regulator Co. has completed this new and greatly expanded warehouse for operations in the Southwest. The company closed its Houston warehouse. The new facilities are at Longview, Texas.

INFILCO, INC. has formed a new Petroleum Sales division to be managed by **Orlen E. Baker.** He is a chemical engineer with a M.S. degree from Purdue University. He has had several years experience with the water problems of the petroleum industry and has made extensive studies of water and brine treatment for secondary recovery of oil.


TRIANGLE BRAND
COPPER SULFATE
the Superior Reagent for "Sweetening"
Sweetening in oil refining and processing demands a superior reagent either in the dry form or in aqueous solutions. Triangle Brand Copper Sulfate is versatile and is effective in partly desulphurizing oil, or removing mercaptans, other sulphur compounds, malodorous and resinous substances from cracked distillates.
Triangle Brand Copper Sulfate, 99% pure, will be your reagent of choice once you use it!
PHELPS DODGE REFINING CORPORATION
NICHOLS
TRIANGLE BRAND
REG U S PAT OFF
CHEMICALS
NEW YORK N.Y.
PHELPS DODGE REFINING CORPORATION
300 Park Avenue, New York 22, N. Y.

MANNING, MAXWELL & MOORE, INC. has elected **Charles A. Moore** chairman of the board and **Colby M. Chester, III,** treasurer. **J. Robert Kelley,** president, continues as chief executive officer. Moore, formerly vice president and treasurer, succeeds Chester, who has been associated with the company since 1906 and who did not wish to stand for re-election to the board. Chester, also a vice president of the company, succeeds Moore as treasurer.

THE FLUOR CORP., LTD. has appointed **James P. Kneubuhl,** vice president, utility sales; **George H. Dieter,** vice president, foreign sales, and **David S. Tappan,** vice president, domestic sales. Kneubuhl, a 1938 graduate of Stanford University, joined Fluor in 1941. He successively held positions in engineering and sales, and became vice president of Eastern area sales. In 1955 he became vice president of sales, Engineering and Construction division.

Dieter graduated from Annapolis in 1929 and took a three-year post graduate course in physics at Oxford University, England. He joined Fluor in 1940 as a sales engineer. In 1952 he was appointed vice president, Western area sales. In 1955 he was named vice president of sales, Fluor Products Co.

Tappan graduated from Swarthmore University in 1943. Following four years of active duty with the navy, he attended Stanford University where he received a M.B.A. degree in 1948. He joined Fluor in 1952 as administrative assistant to the vice president in charge of sales. In 1955 he was appointed administrative assistant to the vice president and general manager, Engineering and Construction division. In 1957 he was appointed district sales engineer, New York sales office. The three will headquarter in Fluor's Los Angeles office and will report to the vice president and general manager, Engineering-Construction division.

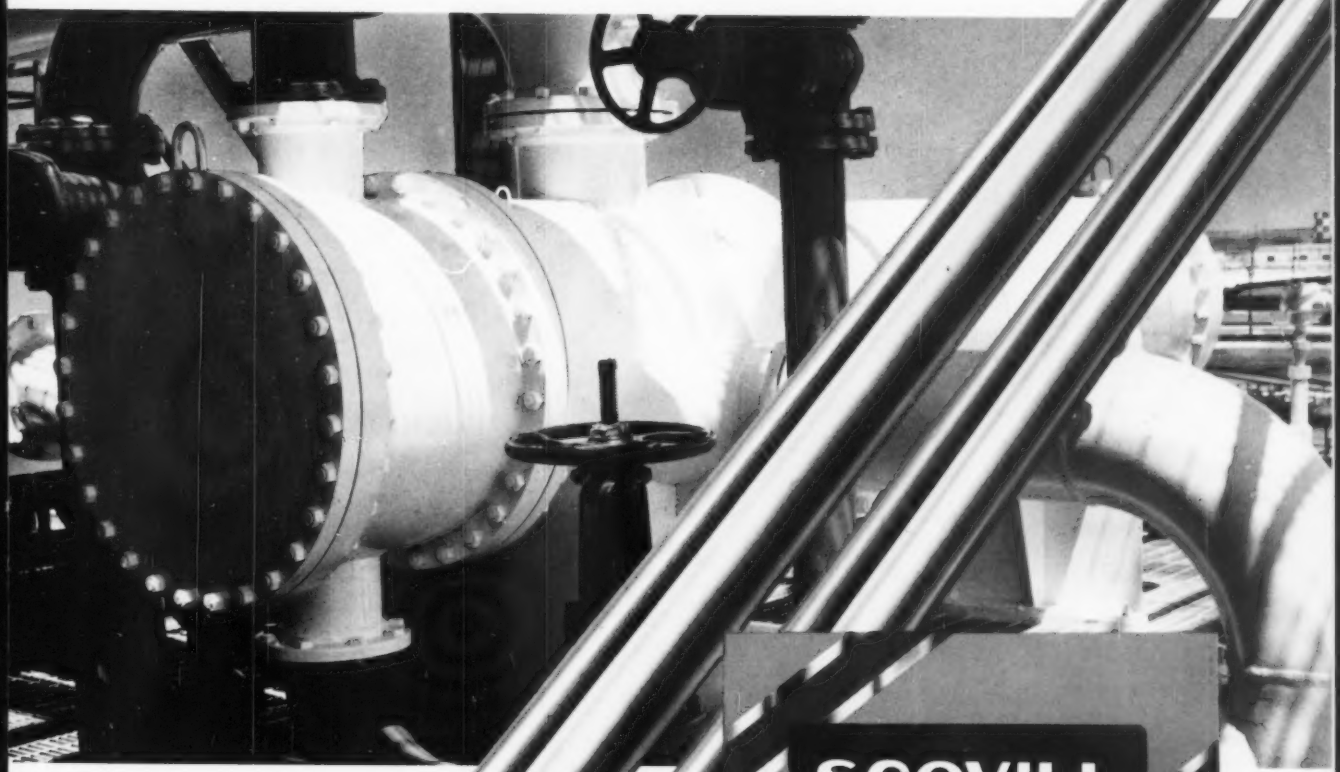
WORTHINGTON CORP.'s Compressor and Engine division has named **Walter E. Max** assistant general manager. He joined Worthington in Buffalo in 1934 as an apprentice in the Machine Shop. **Howard E. Ewell** was appointed manager of manufacturing, succeeding Max. He is a 1939 graduate of Clarkson College in mechanical and electrical engineering. He joined Worthington upon graduation.

MAGNETROL, INC., Chicago, has named **John J. Freeman** vice president and general manager. Previously with Interna-

For more data on advertised products, use Readers' Service Cards, last page.

where trouble-free performance is a matter of pride...

DOW CHEMICAL COMPANY, TEXAS DIVISION, FREEPORT, TEXAS



SCOVILL

Heat exchanger tube

One of the largest of The Dow Chemical Company's manufacturing installations is the Texas Division, where, in complex and brilliantly-painted plants hundreds of different components are processed and re-shaped to produce more than 40 fundamental chemical products.

Chemical process condensers such as this at The Dow Plant, Freeport, Texas, are vital links in the production chain and are tubed with Cupro-Nickel, 30% Heat Exchanger Tubes.

Combining excellent corrosion-resistant properties with very favorable mechanical properties, Scovill Tubes of this alloy make an important contribution to the trouble-free operation of these key units under very exacting service conditions.

Let Scovill Technical Service . . . most experienced in the field . . . help you establish the best heat exchanger tube specifications for equally trouble-free service in your own heat transfer equipment.

MADE IN U.S.A. TO THE STANDARDS OF AMERICAN INDUSTRY

HEAT EXCHANGER TUBE for Applications from Marine to Petrochemical, from Compressor Intercoolers to "Cat-Cracker" Exchangers, in these popular Alloys . . . Phosphorized Admiralty • Admiralty • Arsenical Admiralty • Red Brass, 85% • Deoxidized Copper • Arsenical Copper • Cupro-Nickel, 10%-20%-30% • Aluminum Brass • Aluminum Bronze, 5% • Muntz Metal • Duplex Tube

SCOVILL MANUFACTURING COMPANY, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone PLaza 4-1171.

9BC58

Creole Petroleum Corporation of Venezuela, one of the world's largest producers of crude oil, has pursued a dedicated course of conservation and maximum utilization of Venezuela's natural resources. In so doing, complex engineering problems in gas injection have been created.

An organization of the magnitude of Creole can readily command the very best engineering and construction talent available . . . and Brown & Root felt signally honored when in 1952 they were awarded a contract to design and construct a 60,000 horsepower gas injection station, to be located 7 miles from shore in Lake Maracaibo. The job was loaded with "firsts" and superlatives. For example, it was the first time centrifugal compressors were ever used to compress gas to 2000 p.s.i. This tremendous amount of horsepower was to be housed on a platform in 62 feet of water, with all the related problems of vibration, corrosion, noise and self-containment.

Evidence that the client was pleased with this $20 million project came when Brown & Root was awarded a contract to design and construct Conservation Plant Tía Juana Two of 84,000 horsepower, and then again Brown & Root was successful in obtaining the design and construction contracts for Tía Juana Plant Three of 98,000 horsepower. Conservation Plant Bachaquero One, Creole's fourth repressuring station, is currently on Brown & Root's drawing boards.

BROWN & ROOT, INC. *Engineers - Constructors*

POST OFFICE BOX 3, HOUSTON 1, TEXAS

Brown & Root, S. A., Panama City, Panama
No. One Wall Street, New York 5, New York
P. O. Box 4140, South Station, Edmonton, Alberta
Pennsylvania Building, Washington, D. C.
Brown & Root Construcciones, S. A., Caracas, Venezuela
Brown & Root de Mexico, S. A. de C. V., Mexico City, Mexico
Brown & Root, LTDA., Santos, Sao Paulo, Brazil
CABLE ADDRESS – BROWNBILT

tional Register Co., Chicago, he has a B.S. degree in industrial administration and engineering from Yale University, and M.B.A. from Harvard University.

W. R. GRACE & CO.'S Davison Chemical division has appointed controllers for its three operating units, with full responsibility for financial and accounting activities. They are **John L. Dowell,** Chemicals; **A. H. Hanssen, Jr.,** Mixed Fertilizer; and **Edgar L. Linthicum, Jr.,** Agricultural Chemicals.

AMERICAN CYANAMID CO.'S Pigments division has established new sales and warehousing facilities at Charlotte, N. C. **F. A. Sauter** will be sales representative in charge, serving North and South Carolina, Virginia and Eastern Tennessee.

SOHIO CHEMICAL CO. has named **William J. Witham** manager of industrial sales. Having joined Sohio in 1947, Witham has held various engineering and production assignments and was superintendent of blending, shipping and dry ice at the time of his new appointment.

BORN ENGINEERING CO., Tulsa, and **H. & E. Lintott, Ltd.,** Horsham, Sussex, England, have entered an agreement under which Lintott is granted exclusive franchise to sell, manufacture and erect Born direct fired process heaters in Great Britain and the sterling areas.

ACHESON COLLOIDS CO. has named **Michael G. Blickensderfer** service engineer for Wisconsin, Minnesota, parts of Illinois and Iowa. He will headquarter in Milwaukee. Blickensderfer was formerly in Acheson Colloids' Cleveland office serving the Northern Ohio territory.

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd Federal and Dearborn Streets, Chicago 16, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the registry.

Cyclobutane
Benzenepentacarboxylic acid
1,2,3,5-Benzenetetracarboxylic acid (Prehnitic acid)
p-Chlorocumene
1-Chloro-2-methylbutadiene-1,3
2-Chloro-4-methylpentane
2,4-Dichloropentane
Dicobalto octacarbonyl
Dilauryl phthalate
3,3-Dimethyl-1-butanol
5,5-Dimethylheptene-3
N,N-Dimethyl phenylammonium iodide
2-Ethoxypropane
2-Ethyl-n-butyl chloride
4-Ethyl cyclohexanol
Furfuryl cyanide
N-Hexyl azide
2-Methyl-n-butyl chloride
Nonanol-5
Vinyl sulfide

THE WALWORTH CO. has named **Grove Valve and Regulator Co.,** Oakland, Calif., sales agent for specialized products to certain companies.

ARTHUR G. McKEE & CO. has named **E. C. Scoville** director of purchases succeeding **T. W. Rutledge** who is retiring. After joining McKee in 1925 as an engineer, Scoville became purchasing agent in 1947 and acting director of purchases in December, 1958. He spent considerable time in several European countries during construction of plants there by McKee. He received his B.S. degree in mechanical engineering from Case Institute of Technology in 1925.

Scoville

THE INTERNATIONAL NICKEL CO., INC. has named **John N. Ludwig, Jr.,** supervisor of metallurgical services with headquarters at the Pittsburgh office. He was formerly with Electro Metallurgical Co.

GOULDS PUMPS, INC. has named **A. W. Woodbury** assistant sales manager, engineering, Seneca Falls, N. Y. He has been

Suppliers . . .

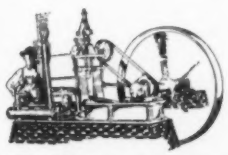
branch manager of the New York office several years. **Lee Topp** assumes Woodbury's former position. He has been with Goulds since April, 1957.

NATIONAL LEAD CO. has named **George B. Coale** and **Graham W. Corddry** directors. Coale is a vice-president of the company and general manager of the Bariod division. Corddry is manager of the Titanium division.

LINDE CO. plans construction of a large liquid oxygen and nitrogen producing plant near Huntsville, Ala. The new plant, which will be capable of producing 100-million cubic feet of oxygen and nitrogen per month, will be completed early in 1960.

A. P. GREEN FIRE BRICK CO. has acquired **The Climax Fire Brick Co.,** Climax, Pa. No changes in the operating staff will be made and Climax will continue to produce its present line of products.

HILLS-McCANNA CO. has elected to its board of directors **G. Corson Ellis,** partner, A. T. Kearney Co.; **A. O. Steffey,** president, Butler Brothers; **J. Scott Wells,** product manager, General Foods



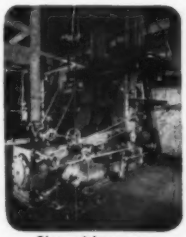
1856 Frick Steam Engine

TRADE FRICK MARK

350-Ton Compressor, of 1896

ONE NAME, *One Independent Company, One Standard of Excellence Since 1853*

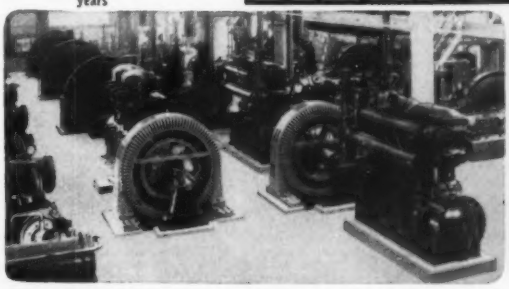
We're decidedly in business at the old stand, under the same experienced management as heretofore, and welcome the chance to serve both old and new customers. Let us quote on your air conditioning, refrigerating or ice-making needs: write . . .



Steam-driven compressor in service at Peoria, Ill., 60 years

WAYNESBORO, PENNA., U.S.A.
FRICK CO.

Enclosed compressors, introduced 1915, have useful life of 40 years



Frick heavy-duty refrigerating compressors have operated 30 years at Celanese Corp., Amcelle, Md.

"ECLIPSE" machines handle any refrigerant at any temperature.

For more data on advertised products, use Readers' Service Cards, last page.

AMOCO CHEMICALS—A NEW RESOURCE

Grease Thickener 0578 is a preformed, nonsoap, all organic gelling agent unlike any other thickener. It is a free-flowing, dust-free, granular material that is easy to handle and work with. Grease Thickener 0578 can be readily dispersed in oil to make greases by heating, cooling and colloid-milling. This thickener—an AMOCO Chemicals exclusive—is now being trial marketed.

A dropping point of 480° F. is typical for No. 2 greases formulated with Amoco's new Grease Thickener 0578.

Using Grease Thickener 0578, grease compounders can offer products for both industrial and automotive lubrication that have the widest possible performance range. NLGI No. 2 greases can be formulated with an ASTM dropping point of 480° F.—at least 100 degrees higher than conventional lithium soap greases. And greases so formulated have demonstrated superior mechanical, thermal, and oxidation stability. They are water resistant and are not readily susceptible to oil leakage.

The full story on Grease Thickener 0578, together with technical assistance in formulating greases using it, is yours. Your inquiry will receive immediate attention.

AMOCO CHEMICALS

AMOCO CHEMICALS CORPORATION

910 South Michigan Ave., Chicago 80, Illinois

Corp., and **H. Richard Wilking,** assistant vice president, Trust department, the First National Bank of Chicago.

ACF INDUSTRIES, INC. has named **J. M. Gruitch** director of government products. He was formerly a director of defense products for ACF's American Car and Foundry division.

AMERICAN CYANAMID CO.'s Petrochemicals department has named **James M. McNamee** sales manager. He has been with Cyanamid since 1950, when he joined the Stamford, Conn., laboratories. Supplier

CONSOLIDATED ELECTRODYNAMICS CORP. has established a government liaison office in Dayton, Ohio. **James W. Spry,** a military liaison engineer with Grand Central Rocket Co. the past two years, will be in charge of the new office.

THE CARPENTER STEEL CORP.'s Alloy Tube division has moved its Western regional sales headquarters from San Francisco to 2304 Huntington Drive, San Marino, Los Angeles.

GENERAL ANILINE & FILM CORP. has elected **Dr. Jesse Werner,** formerly director of commercial development, Dyestuff & Chemical division, a vice president. He joined the company in 1938 as a research chemist.

LEEDS & NORTHRUP CO. has sent **G. Foster Rucker,** formerly manager at Los Angeles, to Philadelphia as manager, Market Development division, succeeding **Nathan Cohn,** advanced to vice president, technical affairs.

MID-STATES CHEMICAL CO., Mt. Vernon, Ill., has moved to new and larger quarters. The new building includes a showroom for products, modern offices and complete manufacturing and warehousing facilities. The new address is Route 148, Waltonville Road, Mt. Vernon, Ill.

B-I-F INDUSTRIES, INC., Providence, R. I., has appointed **Heach Sales Co.,** Denver, as sales agent of petrochemical equipment in the Denver territory, including Southeast Wyoming, Colorado and the "Four Corners" region.

GENERAL AMERICAN TRANSPORTATION CORP. has elected **Jack I. Levy** a director, vice president and general counsel. He was previously with the law firm of Sonnenschein, Lautmann, Levinson, Rieser, Carlin & Nath, with whom he had been since 1935.

GEIGY INDUSTRIAL CHEMICALS CO. has added **John J. Paredes** to its sales force, with headquarters in St. Louis. A graduate of Boston College, he received his A.B. degree in Chemistry in 1950.

Suppliers . . .

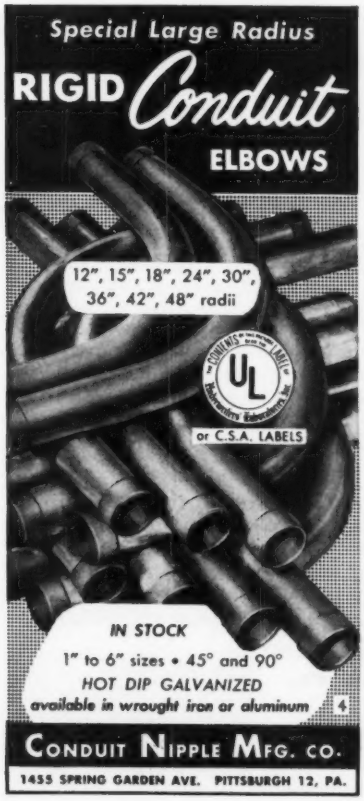
FISCHER & PORTER CO.'S new Birmingham office has been opened by **Charles Goldsmith.** Formerly a sales representative for Delta Refining Co., Memphis, Goldsmith attended the University of Alabama.

Groom

Applegate

ROCKWELL MANUFACTURING CO. has named **Michael P. Groom** branch manager of the new El Paso sales office, Meter and Valve division. **John R. Applegate** has been named branch manager of the division's Detroit sales office. The El Paso office is being transferred from Midland, Texas, and from the company's Southwest region to the midwestern region.

JONES & LAUGHLIN SUPPLY DIVISION has named, as field salesman, **Jack H. Rankin,** Kermit, Texas; **John W. Snyder,**


Special Large Radius
RIGID Conduit
ELBOWS
12", 15", 18", 24", 30", 36", 42", 48" radii
or C.S.A. LABELS
IN STOCK
1" to 6" sizes • 45° and 90°
HOT DIP GALVANIZED
available in wrought iron or aluminum
CONDUIT NIPPLE MFG. CO.
1455 SPRING GARDEN AVE. PITTSBURGH 12, PA.

Specialists
IN TANK AND VESSEL—
Design, Fabrication, Erection, Testing and Repairs
Tanks and vessels—from the first preliminary design to the finished job, completely tested and ready for service—are our exclusive interest. We have no other departments. Every thought is given to producing the very best tank or vessel possible. Next time, let us figure your requirements—whether it's one tank or a hundred-plus tank farm installation.
Fabrication
Erection
X-Ray Testing
ELLERBEE BROTHERS
P. O. BOX 857
PORT ARTHUR, TEXAS

Suppliers . . .

Alice, Texas; **Gordon N. Jones,** North Dakota store; **Gary N. Griffiths,** Odessa, Texas; **Larry F. Ransdell,** Oklahoma City sales office, and **Jerre B. Williams,** El Dorado, Ark.

THE DOW CHEMICAL CO. has named **Fielding H. Yost, Jr.,** assistant to the director of corporate relations, with headquarters in Midland, Mich. Thomas M. Gow succeeds Yost as manager of the Cleveland sales office.

PENNSALT CHEMICAL CORP.'s Corrosion Engineering Products Sales department has named, as new representatives at the Natrona, Pa., sales and service headquarters, **William S. Ewing, Thomas A. Hanna,** and **Allen M. Smith II.**

ACF INDUSTRIES, INC. has elected **Francis Cabell Brown** director. He is president and chairman of the board of Schering Corp., New Jersey pharmaceutical manufacturing firm.

THE PITTSBURGH-DES MOINES STEEL CO. has opened new district sales offices in New York and Baltimore. The New York office assumes duties previously handled by the Newark, New Jersey office, now discontinued.

A group of new application engineers, trained at Crouse-Hinds Co. in January, are pictured during a break, with Arthur F. Uhrlandt, director of field sales. They studied all company product lines, and will return to field offices across the country to continue their on-the-job training.

THE QUAKER OATS CO. has appointed **J. J. Howe** Eastern district sales manager for the Chemicals division. He joined Quaker Oats in 1947, and prior to his present appointment was sales supervisor, New York office.

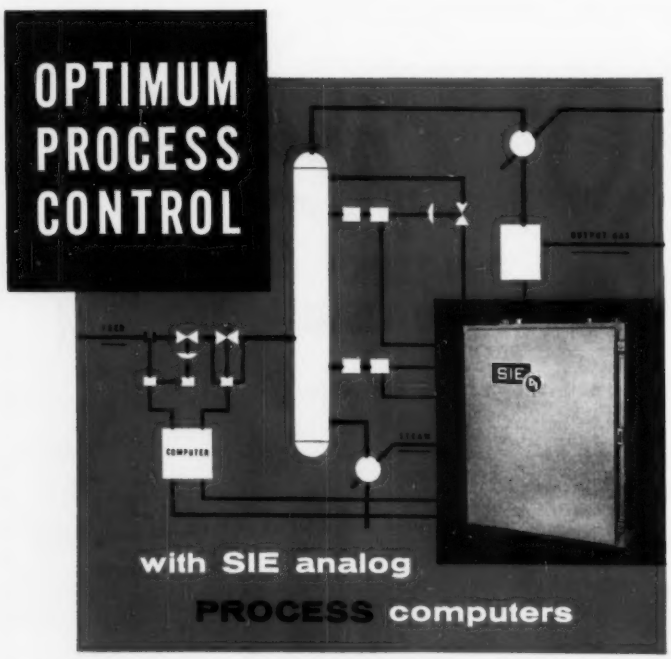
CHASE BRASS & COPPER CO. has named **Clifton D. McCarra** district manager of the warehouse and office, Dallas. He has been with Chase's Dallas office since 1949.

TRETOLITE CO.'s R. T. Thompson, sales engineer, at Houston, has retired. Before joining Tretolite 11 years ago Thompson had served nearly 24 years with Stanolind Oil Purchasing Co.

SHAND AND JURS CO. has appointed Commercial E Industrial de Fornos Werco as its unrestricted sales representative for Brazil. The Brazilian firm will handle Mechanical division and Electrical Products division sales.

GENERAL AMERICAN TRANSPORTATION CORP. has acquired Traylor Engineering and Manufacturing Co., Allentown, Pa. Traylor will continue to operate independently under management of Fuller Corp., General American's subsidiary.

DRESSER INDUSTRIES, INC.'s Manufacturing division has promoated **E. R. Carey** to assistant sales manager, regular prod-



no ● moving parts
no ● vacuum tubes
no ● contacts

SIE CM-2 Analog Computers provide precise control in chemical, petrochemical, refining, and similar process applications, to a degree never before possible. Using this new concept, process variables are taken into account in adjusting set-points automatically to achieve optimum output yield.

Using Magnetic Amplifiers and Transistors CM-2 Series Computers have a **trouble-free life expectancy in excess of 100,000 hours,** yet in a typical fractionator application now in operation, computer cost was less than $5000.

Write for Brochure Describing Applications in Feed-Ahead, Feed-Back, and Operator Guidance computations. SIE engineers will welcome the opportunity to discuss the use of CM computers in your specialized process control applications.

SIE

SOUTHWESTERN INDUSTRIAL ELECTRONICS CO.
A Division of Dresser Industries, Inc.
2831 Post Oak Rd. • P. O. Box 13058 • Houston 19, Tex.

PRIME AND SUB-CONTRACTORS FOR MILITARY ELECTRONICS INSTRUMENTATION AND GROUND SUPPORT EQUIPMENT

ucts. He has been manager of general markets sales. **John P. Lord,** formerly business manager for welding fittings, becomes manager of general markets sales.

THE BABCOCK & WILCOX CO.'s Tubular Products division district sales office, Atlanta, has been moved to 464 Peachtree Building, 805 Peachtree Street, N.E., Atlanta 8.

ARTHUR G. McKEE & CO., Petroleum Refinery division has appointed **Macauley Carter** sales manager. Before joining McKee in 1946 as a sales representative, he was treasurer of Universal Oil Products Co.

THE PFAUDLER CO. has named **Richard H. Starrett** chief production engineer. Chief engineer at Pfaudler's Elyria plant since 1952, he joined the firm in 1948 as a mechanical engineer after gaining experience in consulting and process engineering. Starrett attended Brown University and graduated in 1941 with a B.S. degree in mechanical engineering. He is a member of ASME and NSPE.

Starrett

KEROTEST MANUFACTURING CO.'s Steel Products division has named **William I. Pell** sales manager. Formerly manager of pipe sales for Colorado Fuel and Iron Corp. he acted in the same capacity for Worth Steel Co.

WESTINGHOUSE ELECTRIC CORP.'s Apparatus division has appointed **K. M. Patterson** manager of Headquarters Sales departments, East Pittsburgh, Pa. Succeeding Patterson as manager of the division's Industrial Sales department is **C. E. Hammond,** formerly assistant manager for the division's South Pacific district, Los Angeles.

GARDNER-DENVER CO. has elected **Charles M. Mayhew** a director. A vice-president of Mayhew Machine and Mayhew Supply Companies, Dallas, he has been active in the firm since receiving a B.S. degree in business administration from Texas A & M college in 1940.

YUBA CONSOLIDATED INDUSTRIES, INC. has named **Monte Lindmoe,** formerly executive vice president, Southwest Welding and Manufacturing Co., vice president and a director of sales for all company operating divisions and subsidiaries.

Petroleum Refiner Classified Ads

Petroleum Refiner New Classified Rates

RATES: Regular Classified (undisplayed) set in this type: 20 cents per word. Minimum charge, $4. Blind box address in our care counts six words. Replies forwarded without charge. **Display Classified ads,** set in suitably larger type with ruled border, $12.50 per column inch. Ten percent discount for two or more insertions of same copy in consecutive issues. **All Classified ads payable in advance.** Copy deadline: 25th of month preceding date of issue. Send copy and checks to: Classified Advertising, Petroleum Refiner, P. O. Box 2608, Houston, Texas.

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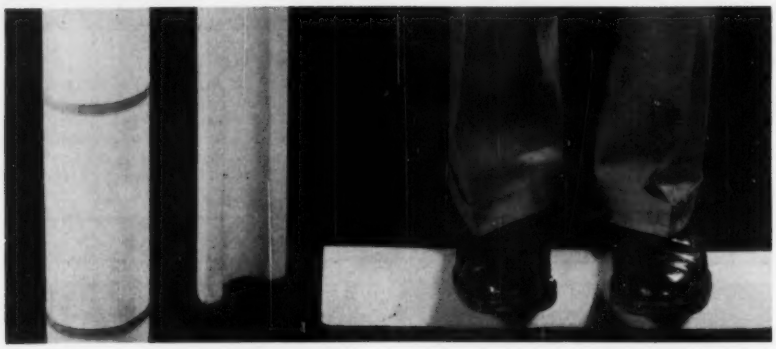


New Polyurethane Has Very Low K-Factor

Rigid-Foam pipe insulation, the first pre-molded rigid polyurethane pipe insulating material, is said to have substantially greater thermal efficiency than any low temperature insulation on the market. Specifically designed for low temperature application down to —300 F, the new material has been thoroughly field tested and is available nationally.

A U. S. Testing Laboratory report indicates that at a mean temperature of zero F, it has a K-factor of only .096 btu per square foot, hour, degree F—less than one-half that of any other known industrial insulation suitable for low temperature use.

It does not require special installation tools or materials. It can be applied to piping with ⅜- or ½-inch steel bands or with 16 gage tie wires and joints sealed with low temperature mastics.

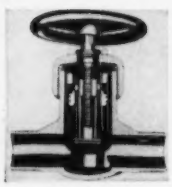
The insulation resists damage in handling, application and service because of its great compressive strength, illustrated by the man standing on it.

Rigid Foam Pipe Insulation is currently available in all standard IPS sizes from ½ to 12 inches in diameter. Additional sizes will be available soon. Thicknesses range from ¾ to 2½ inches in ½ inch increments, and the molded pipe half-sections are three feet long. Baldwin-Hill Co.

Circle E1 green card, last page

Plastic Valve Has Full-Pipe Cross-Section

A new valve of all plastic construction just introduced, features an absolutely dependable method of tight sealing. Employing a telescopic arrangement, instead of a diaphragm, a soft-rubber cup is forced to the concave bottom of the passage. Because of its flexibility, the cup, under pressure from the stem, seals on all sides against the walls of the body casing, positively shutting off fluid flow.



On the upper part of the shut-off body there is a lipped packing which prevents the fluid from contacting the stem or from leaking out of the valve. The stem is located in two telescope type sleeves which slide inside each other. This also prevents ingress of the medium. A gasket prevents bearing grease from finding its way into the casing. The outer telescope sleeve acts simultaneously as a pressure tube in the plunger, reinforcing the soft rubber cup from within. Material flowing through the passage under considerable pressure is not forced out to the side during closure. Thus, even under maximum pressure, the cup locates precisely in the position provided in the passage.

The smooth, corrosion-resistant plastic walls offer no resistance to the sliding movement of the cup, thereby providing easy adjustment of the spindle.

Foreign matter in the line—sand, grit, stones and the like—does not impair the valve because the soft rubber cup is so flexible that it accommodates these particles without harming its sealing characteristics and without itself suffering damage.

The straight through design, with no obstructions and with no reduction in the cross sectional area in full open position, eliminates pressure loss.

The valve body, cover, handwheel and soft rubber cup can be supplied in various plastic materials best suited to the material to be handled. The valve is equally suitable for installation in metal or plastic piping systems. It can be supplied with screwed or flanged ends or with socket ends. The working pressure is 145 psi although all valves are tested at 230 psi. Available sizes from 1 to 4 inches. W. S. Rockwell Co.

Circle E2 green card, last page

Chromatograph Separates Faster Than Packed Column

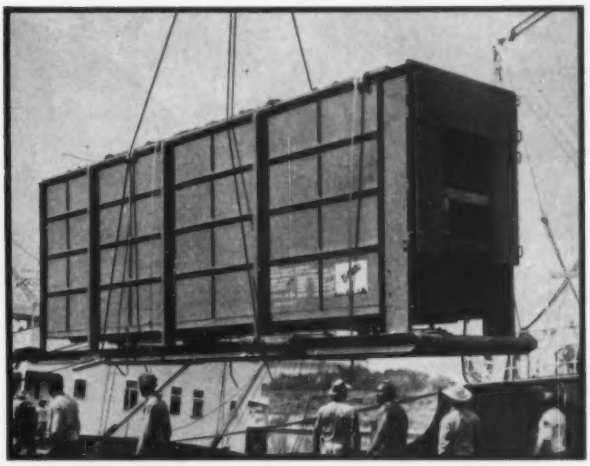
A new high resolution, high sensitivity instrument, representing a major advance in gas chromatography instrumentation, has been developed.

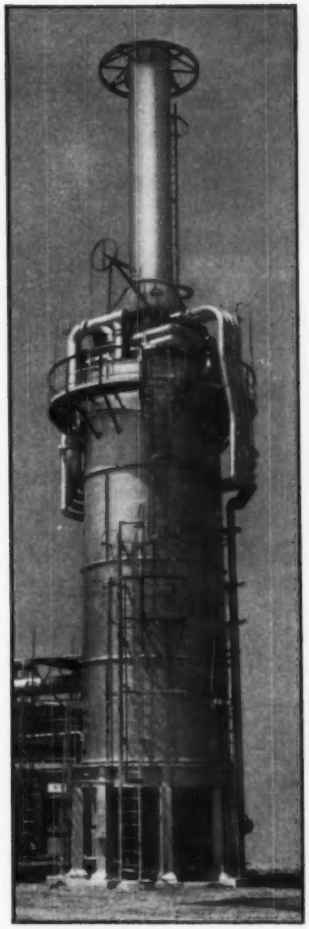
Designated the Model 208 Vapor Fractometer, it is the first commercial instrument to offer, as standard, a flame ionization detector. This new-type detector is generally recognized as the most sensitive general purpose one available for gas chromatography.

It is also the first commercial instrument to incorporate the new high resolution Golay, or capillary columns.

These design features enable the instrument to pick up components at a level of approximately 10^{-9} grams

BORN BUILDS BETTER HEATERS

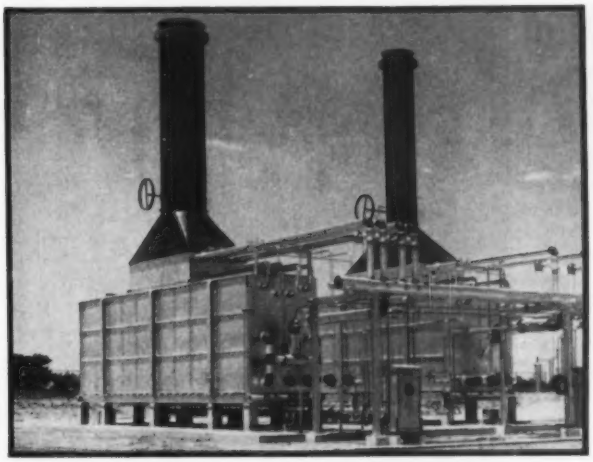




For one thing BORN builds nothing but heaters . . . heaters for every process heating requirement. For over forty-two years BORN has specialized in this field and as a result BORN HEATERS are known for their close control, economical, trouble-free operation plus exclusive safety features not found on any other heaters. During this time BORN HEATERS have built a reputation for producing day after day with no expensive "down-time" for frequent servicing and repairs.

No wonder BORN HEATERS are specified time and time again by clients whose names are the Who's Who of the Oil Industry.

For the complete story on a BORN HEATER to fit your needs, write, wire or call your BORN representative. He's anxious to serve you.



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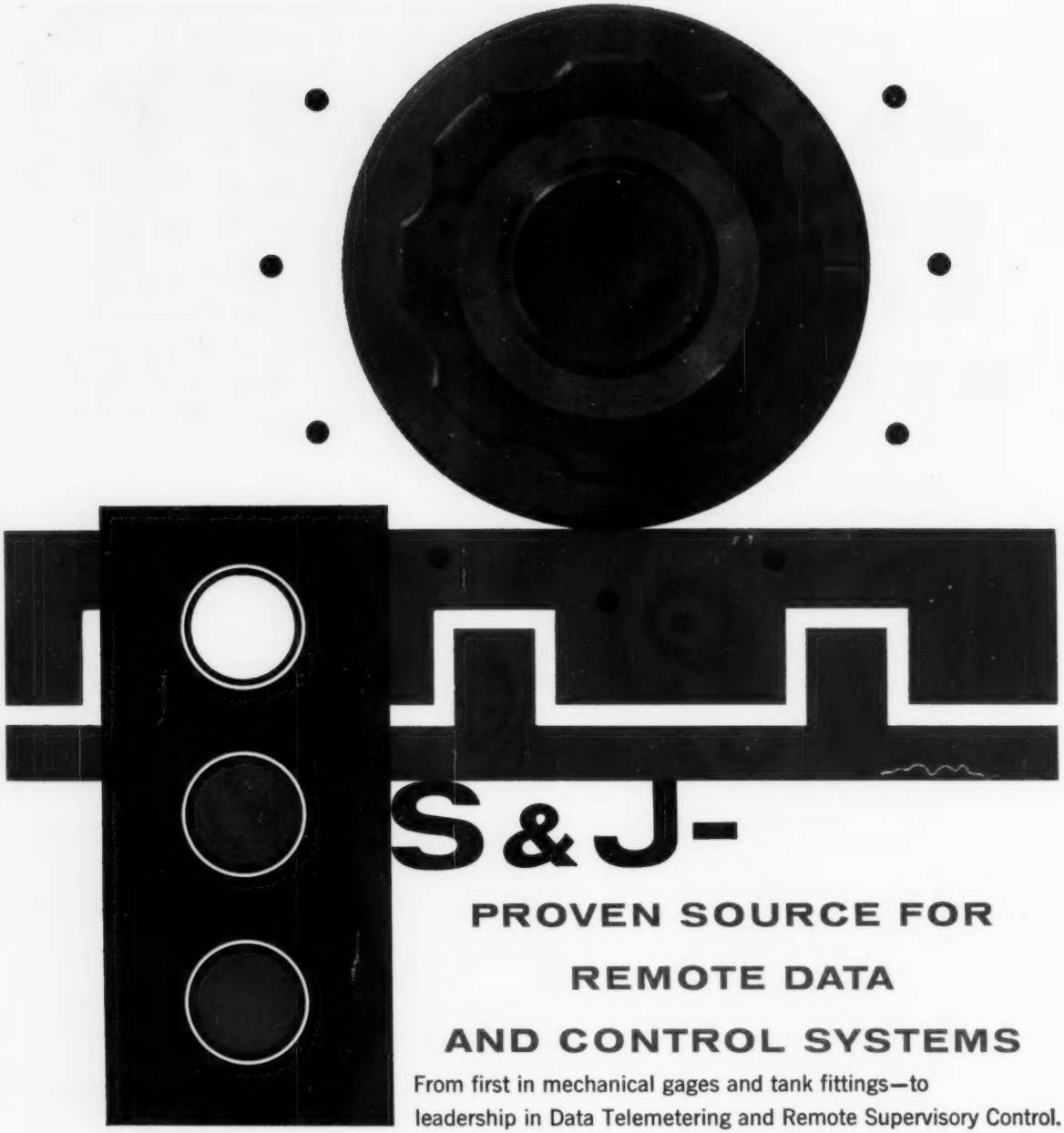
For more data on advertised products, use Readers' Service Cards, last page.



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without difficulty. At 160 F., it will separate hydrocarbon components from C_5-C_{12} in a reasonable time, whereas a conventional packed column of the same substrate might conveniently separate only C_5-C_{11} when run at the same temperature. Perkin-Elmer Corp.

Circle E3 green card, last page

Welding Gas Regulator Eliminates Gage Breakage

A new line of Oxweld gageless regulators represents a revolutionary improvement in the field of industrial gas regulation. In addition to the lower initial cost, the new regulators eliminate forever the costly and annoying problem of gage breakage and replacement.

Designed for use with oxygen, acetylene or propane on cylinders or manifolds, the new regulators provide the same safe, dependable and accurate performance found in conventional Oxweld regulators. Known as the R-550 (Oxygen), R-551 (Acetylene) and the R-552 (Propane), the new large-capacity, single-stage regulators have stem-type valves and are designed with an absolute minimum of exposed parts to eliminate maintenance and assure long life. They are

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For ring-type flanged joints in high pressure lines. Made of soft iron, standard steel alloys or any non-ferrous metal to any desired cross section. Ask for Bulletin 563.

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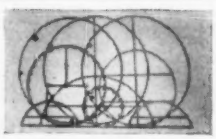
Made in any size or shape needed in double-jacket type. Also cut from solid metal or sheet packing. Ask for Bulletin 564.



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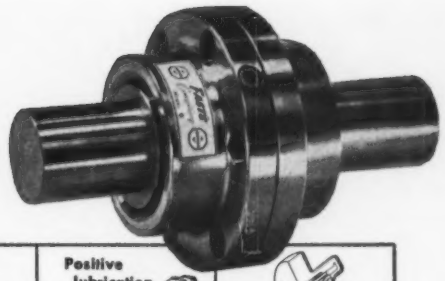

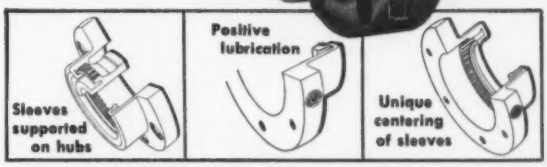

reduces downtime and upkeep for light-to-medium drives!

Now you can profit from the durability and economy of famous Fast's couplings in a smaller and lower-cost version—available in 5 sizes for shafts ½" to 3⅛" in diameter.

The Model B coupling gives you the same features that have made Fast's the world's leading coupling for over 35 years. You get the same trouble-free performance, longer service life and lower maintenance costs. You also get prompt delivery because stocks are on hand to meet practically every need. Free engineering service is also available.

Write today for more details to KOPPERS COMPANY, INC., Fast's Coupling Dept., 6105 Scott Street, Baltimore 3, Maryland.

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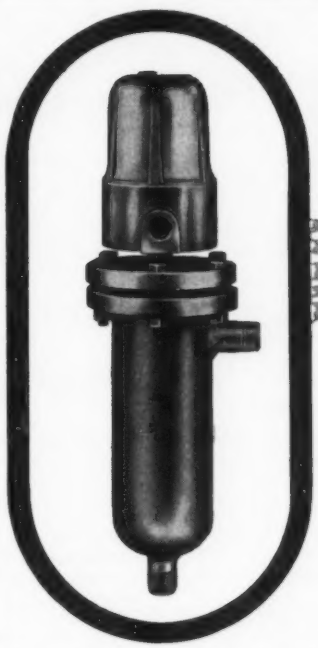

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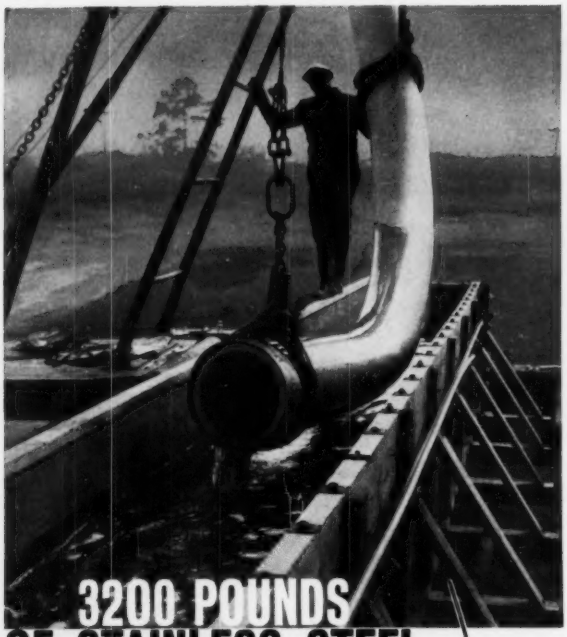

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The 3200 pound, 16 foot stainless steel pipe section shown above is an example of the piping to be used in the nation's largest atomic power plant. The pipe was fabricated in Houston by Southwest Fabricating and Welding Company. Before being shipped, every inch of each pipe section was thoroughly inspected to be sure that it was completely free of all dirt, mill scale, oxides, metal elements, and similar deposits. There could be no guesswork. *The pipe had to be hospital clean.* To guarantee that their piping was as clean as clean could be, Southwest called in the Nowery J. Smith Co.

The Smith corrosion prevention specialists have cleaned and passivated 1190 feet of the steel pipe to date. Pipe ranging to 22 inches in diameter, with wall thicknesses to 1.220 inches, was polish-blasted and then passivated to ASTM specifications to preserve cleanness.

If corrosion is a factor in the work-life of your equipment consult with the Nowery J. Smith Company during the design phase of your project. Think Nowery J. Smith Co. for Hot-Dip Galvanizing • Metallizing • Chemical Cleaning • Sand/Shot Blasting • Painting/Coatings • Plastics • Plastic Applications • Vessel Linings

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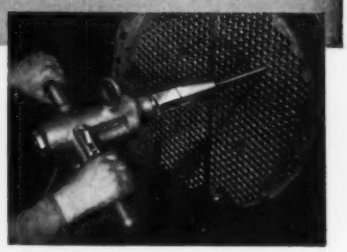


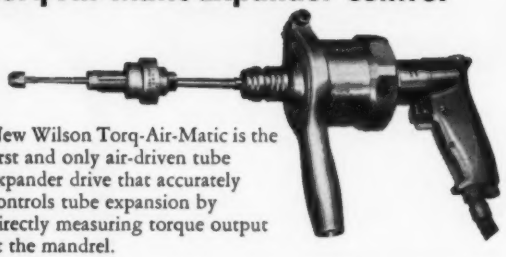
Heavy-Duty TP-301 Cleaner

Positive air-driven, hollow rotary shaft, drill type tool. Tube is scavenged with air or water while cleaning.

Tube Expanders

Wilson Models 41 and 44 Tube Expanders incorporate an improved, adjustable ball bearing thrust collar and are designed for efficient, easy rolling and maximum roll length adjustment for various tube sheet thicknesses.

Torq-Air-Matic Expander Control



New Wilson Torq-Air-Matic is the first and only air-driven tube expander drive that accurately controls tube expansion by directly measuring torque output at the mandrel.

Tube Cutter

Wilson tube cutter is easy to use and does a fast job. Cutter sizes and shanks available to meet all heat exchanger requirements.

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extremely valuable on jobs where regulators are subject to rough handling or switched from cylinder to cylinder frequently.

Delivery pressures are calibrated on an anodized aluminum "Metal-cal" plate on the cap of the regulator and the delivery pressure is shown by an indicator running in the slot alongside of the calibrated reading. As the pressure-adjusting screw is turned in or out, this delivery indicator moves to the desired pressure. Linde Co., Division of Union Carbide Corp.

Circle E4 green card, last page

Insert Butt Weld Fitting For High Yield Pipe

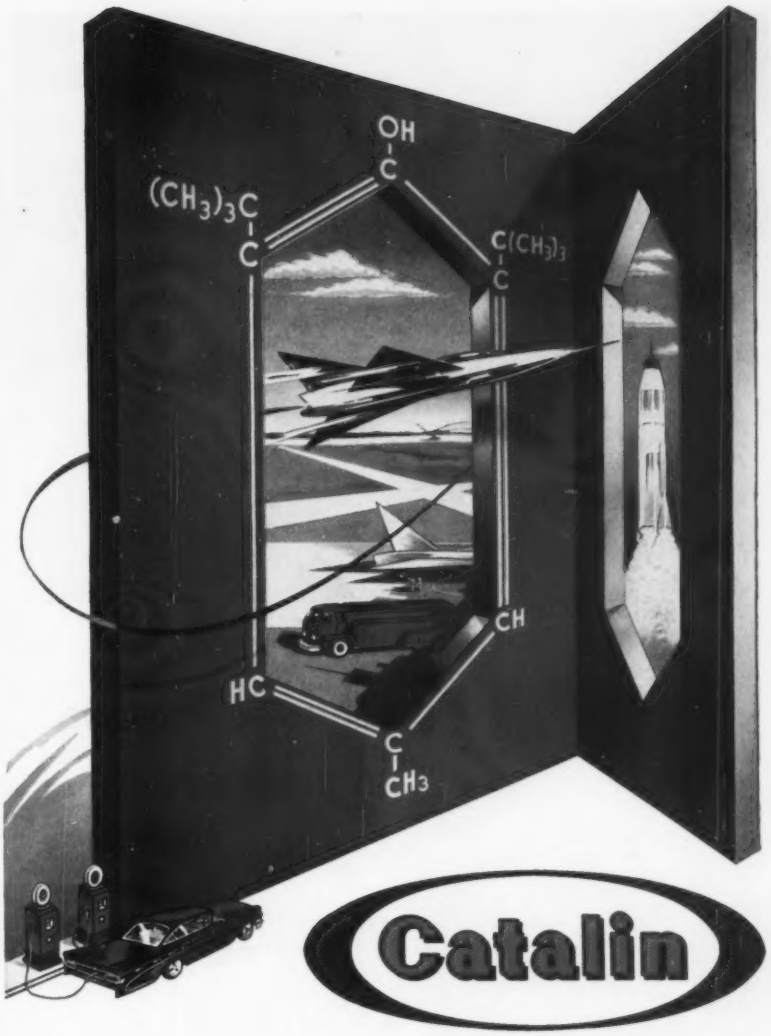
The new Bonney Sweepolet is a forged, integrally reinforced, insert butt welding pipe fitting. Extensive stress analysis tests have proven this fitting to be the strongest, most efficient means of making branch outlets on high yield pipe.

The fiittings assure maximum efficiency of metal placement with minimum weld; optimum distribution of stresses due to both internal pressure and externally imposed loads. They take less time to install and cost substantially less than any other comparable quality fitting on high yield pipe. Bonney Forge & Tool Works.

Circle E5 green card, last page

Cooling Tower Splash Bars Supported By Glass Fibers

A new patented method of supporting filling splash-bars in their industrial cross-flow cooling towers is being used. The filling is supported by molded grids fabricated of glass fiber reinforced polyester resin; non-corrosive, immune to rot and decay. These new supports, hailed as a major advance in cooling tower component design and material usage, will



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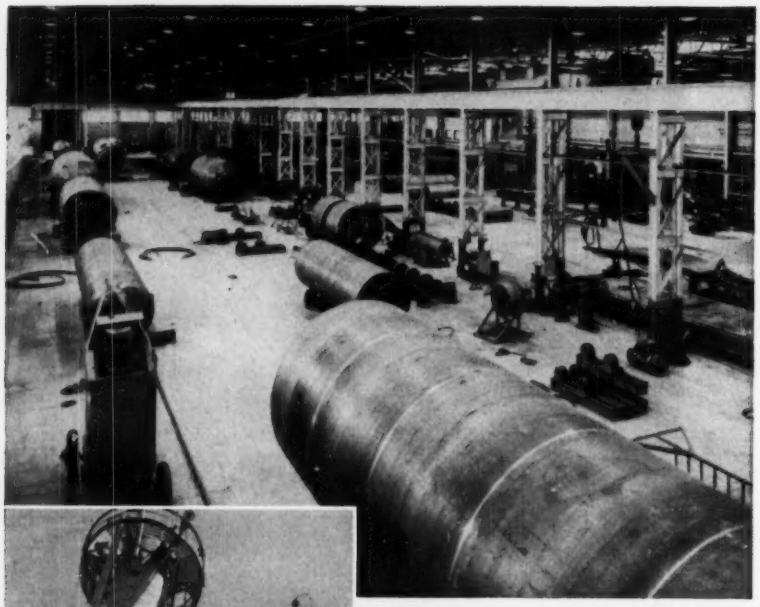

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greatly increase tower service life and reduce maintenance cost. They provide a permanently level splash-bar installation that prevents water channeling with resultant loss of performance, assure a precisely engineered splash-bar arrangement for maximum water breakup and minimize restriction to air flow. The Marley Co.

Circle E6 green card, last page

Admiralty Tube Surface Area Increased 13 Percent

A significant 13 percent increase in the outside surface area of Trufin Admiralty Type S/T was recently announced.

The increase was made coincident with the release of the new product reference catalog on Trufin. The surface increase in admiralty was the result of a redevelopment of fin contour, resulting in savings in tube required for shell and tube heat exchangers using admiralty Trufin tube. This brings the outside surface equal to that of copper Trufin of the same size.

The reference catalog lists all of the sizes, alloys, heat transfer data, application data, etc., for the many types of integrally finned tube available for heat transfer applications. Wolverine Tube, Division of Calumet & Hecla, Inc.

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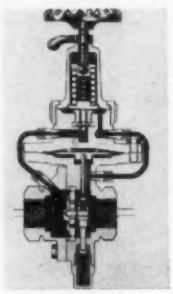
Pressure Reducing Valve's Performance Improved



A ½-2 inch size piloted pressure-regulator has been redesigned to improve its performance by providing minimum maintenance, tight shut-off, and more accurate regulation. It incorporates patented sliding gate and plate seats and new external sensing tubes, Teflon pilot seat, handwheel and thumlock, ball bearing adjustment and other advanced features. Suitable for pressures to 250 psi-wsp and temperatures to 450 F, they are available in ½-2 inch sizes from stock in bronze, cast iron and ductile iron with screwed ends. Uses extend to steam, water, air, oil, gas, and chemicals. OPW-Jordan.

Circle E9 green card, last page

Ethylene Amine Chemistry Covered In New Book

A new book on ethylene amines designed for research chemists and technical personnel has been announced.

Entitled, "Ethylene Amines," the 65-page publication is considered to be the first book providing comprehensive coverage of ethylene amine chemistry.

The contents include properties, reactions, uses, first aid techniques, han-

SAME SLING PRINCIPLE AS IN JET PILOT HELMETS

SAFE AND SURE WITH GENTEX PETROLEUM SAFETY HATS

Slings in Gentex Safety Hats use same design principle as slings in Gentex jet flight helmets. 6-pt. suspension, 3-layer crossover at crown. Rugged polyethylene shell exceeds all Federal Safety specifications, yet the Gentex weighs within ¾ ounce of any safety hat made. No metal parts — fully non-conductive.

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Snap a die head in the ratchet ring . . . cut your thread! It's as simple as that with a RIDGID drop head threader. Heads can't fall out . . . dies reverse quickly for close-to-wall threading. Finest quality RIDGID long wearing dies. Bolt and conduit dies available.

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International Petroleum Exposition
Booths 28-31

Hand Carrier Free With All Sets Except No. 12-R

(Order in sets or any combination)

Exposed Ratchet Type

For pipe—⅛" to 1"—00-R
⅛" to 1¼"—111-R
⅛" to 2"—12-R
For bolts—¼" to 1"—00-RB

Enclosed Ratchet Type

For pipe—⅛" to 1"—0-R
⅛" to 1¼"—11-R

RIDGID

The Ridge Tool Company · Elyria, Ohio, U.S.A.

For more data on advertised products, use Readers' Service Cards, last page.

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STRUCTURAL STEEL and
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We pride ourselves for "on time" delivery. Thoroughly experienced staff of designers, engineers, and fabricators, to furnish the steel you want, when you want it. AISC members. ASME pressure vessels, tanks, heat exchangers, as well as structural steel. Location served by SP and MP railroads, and our dock is on the Intracoastal Waterway. Write, wire or phone for FACT FILE on our complete facilities.

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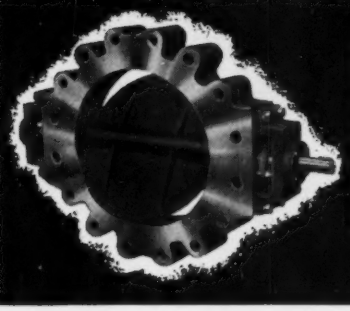
HOW ABOUT
BUTTERFLY VALVES
FOR MANUAL and POWER CONTROL



FISHER-CONTINENTAL Butterfly Valves fit the specifications of a vast majority of applications. They're low cost—more compact than expensive, complex valve installations. And they're easier to operate and service, too.

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FULL FREEDOM OF CHOICE

For gas, vapor, liquid or semi-solid control problems specify Fisher-Continental Butterfly Valves—any size . . . any metal or alloy . . . any temperature . . . any fluid . . . any pressure . . . any condition . . . any operator, manual or power.

For complete details about Fisher-Continental Butterfly Valves send for free literature.

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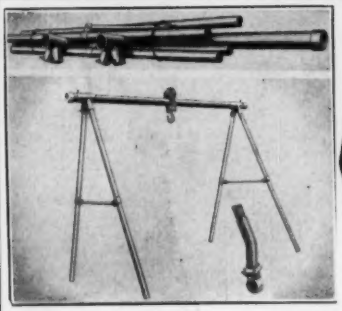
FISHER Controls
SINCE 1880



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QUICKLY SET UP . . . EASILY TAKEN APART

- **COLLAPSIBLE**
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- **ADAPTABLE** to multiple applications
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- **EASILY** transported
- **EASILY** rolled from one room to another

Use on the premises . . . or off the premises

Delivered knocked down. Can be set up or dismantled by 2 men in 10 minutes. Equipped with trolley and set of 4 slip-on boots with casters. Both "A" frames can be compressed at will by user for use in confined spaces. Ideal for plants where gantry is needed in several departments, on or off the premises. One takes the place of many. Ruggedly built for strength and long life.

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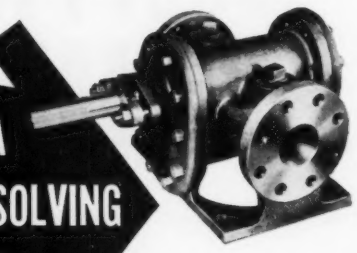

Engineers, maintenance supervisors and plant superintendents with pumping problems swear by SK Rotary Gear Pumps. In case-after-case SK Pumps, used as original equipment or as replacements, have solved "in-service" difficulties and have given years of maintenance-free service. What these pumps have done for others, they can also do for you.

New Bulletin G-1 gives full details on standard SK Gear Pumps. Write for your copy.

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dling and storage, property graphs and a bibliography covering patent and use sources.

In the petroleum industry, ethylene amine intermediates have applications as asphalt additives, reagents in petroleum producing and refining, and as lubricating oil and gasoline additives. They have also proved effective as corrosion inhibitors for oil and gas wells.

In the rubber industry, ethylene amines and their derivatives are used as activators, catalysts, short-stopping agents, curing agents, stabilizers and modifiers in the polymerization and vulcanization of natural and synthetic rubber. The Dow Chemical Co.

Circle E10 green card, last page

Handbook On Muriatic Acid Gives Principal Reactions

The first one-volume basic reference book on muriatic (hydrochloric) acid has just been published.

Despite its wide range of applications, from oil and gas well acidizing to the manufacture of perfumes, the basic information about muriatic acid had never been available in one single handbook in the United States. Dow has answered this need by publishing a 44-page manual titled, "Dow Muriatic Acid."

Illustrated with drawings, tables and graphs, the book covers the history of muriatic acid, properties of muriatic acid solutions, its principal reactions and uses, and Dow's experiences and interest in the product. The Dow Chemical Co.

Circle E11 green card, last page

Hydraulic Filters Cut Maintenance 90 Percent

A new line of "Quick-Top" hydraulic filters, which, the manufacturer claims, cuts preventive maintenance time 90 percent, has just been introduced.

The time-saving claim is based on a unique closure device that permits filter elements to be changed in less than a minute. The closure consists essentially of a hand removable cover which is held in place by a spring steel retainer ring. Using only a screwdriver, the retainer ring can be lifted and the cover removed in less than 10 seconds. The dirty or clogged element can be removed and replaced and the cover sealed back in place in less than a minute. Conventional filters, having bolt-down covers, require 10 minutes minimum for the same operation.

For use with hydraulic oils, fuels, solvents, lubricating oils and other fluids, the filters have been designed to use standard AN-6236 elements which are

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Spark Testing by an experienced technician quickly detects mixed steels. This is one of more than 45 critical Quality Controls used in the production of your order for PACIFIC Mechanical and Pressure Tubing—your assurance that it is Correct to Specs!
The working pressures and fabricating needs of your heat exchanger and condenser tubing are met in the dimensional and chemical accuracy of PACIFIC Tubing...available promptly in straight lengths up to 58'.
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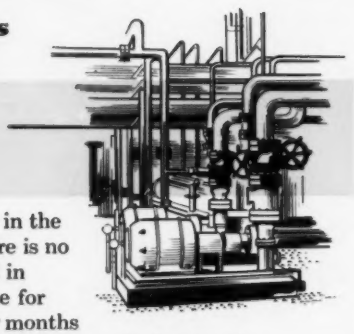
Positive Proof...

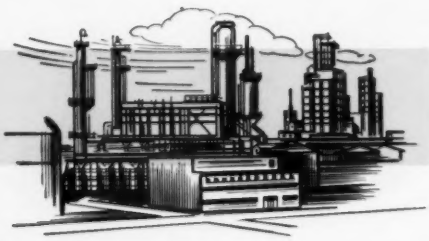
The John Crane Type 9 Shaft Seal Solves Those Tough Liquid Handling Problems

Actual Field Reports



from an Arkansas Refining Plant

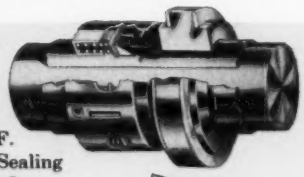
When it comes to avoiding trouble in the handling of naphtha at 420°F., there is no substitute for positive sealing. And in cases like this there is no substitute for "John Crane's" Type 9 Seal. Many months of completely satisfactory operation offers convincing proof.



from a Louisiana Refinery

It takes a "lot of shaft seal" to handle a highly corrosive mixture such as an emulsion of sulphuric acid and butane. This stuff plays real havoc with metals due to its corrosive action. Despite this, Type 9 Seals on twenty seven pumps are pumping month after month in continuous service. At this same location, other Type 9's are effectively handling "fresh" sulphuric acid at the high suction pressure of 400 psi.

In cases like these . . . and in those confronting you . . . the surest answer is the "John Crane" Type 9 Seal.



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Recommended services: all industrial chemicals, corrosives, liquids or gases. Temperatures: –120°F. to +500°F. Pressures: up to 750 psi. Construction: Sealing members of chemically inert DuPont Teflon, metallurgy best suited to service requirements.

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CRANE PACKING COMPANY

Equipment . . .

readily available. The company also can supply special elements of sintered materials, mesh or cellulose where they are necessary.

Inlet to the cylindrical filter body is through the side, and outlet, through the bottom, while the cover is at the top. This arrangement permits elements to be changed without breaking the hydraulic line.

Units rated for flow of 15, 30, 60, or 90 gallons a minute at temperatures from —65 to 200 F are available in each of three series. Series 600 is for use with systems having maximum pressures of 250 psi; series 650, for 1,000 psi, and series 700, for 5,000 psi. Consolidated Diesel Electric Corp.

Circle E12 green card, last page

Top Opening Check Valve For Easy Maintenance

A new top entry swing check valve was designed for oil process lines. The picture illustrates quick removal of parts which is possible through the valve's top entry, designed for fast opening and pressure resistant closure. On the right is the valve's precision manufactured bronze clapper, engineered to provide quiet operation and effective closure when the flow pressure drops. On the left is the threaded top entry cap with its octagon-shaped head for opening and closing conveniences. Shown in the foreground are the two remaining parts of the valve, a hardened steel hinge pin, and the brass plug which holds it in place. This is the first check valve that can be insulated against electrolytic action. Clayton Mark & Co.

Circle E13 green card, last page

Condensed Catalog of Low Voltage Electric Equipment

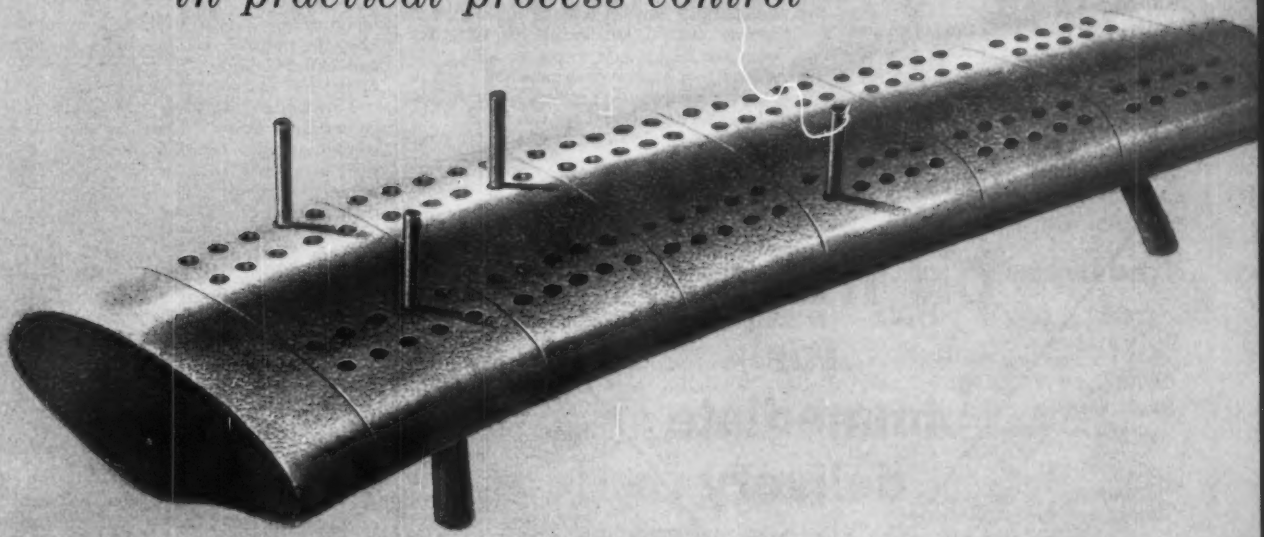
An 84-page "Buy Log" of low-voltage distribution equipment has been released.

The Buy Log serves as a condensed buying catalog for products including circuit breaker load centers, fuse puller panels, safety switches, wireway, molded-case circuit breakers and enclosures, lighting panelboards, distribution panelboards and busway.

It is new in format and content and

SEVEN GIANT STEPS FORWARD

in practical process control



GENESYS

Filling the void in *practical* process control, Genesys now offers reliable, economical computer control systems specifically developed for your requirements. The unique Genesys systems approach provides long needed user benefits at reasonable cost. No precise knowledge of process dynamics is necessary — process operation is optimized through adaptive control methods. Designed from inception as a process control computer, the Genesys System features extreme reliability and simplicity of operation through advanced logical design. Find out how Genesys takes seven giant steps forward in refinery and pipeline automation. Write for "Evolution in Process Control."

Designed and built for industrial and business applications, Genesys Control Computer Systems provide many exclusive advantages at lower cost. Compare Genesys.

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designed so that application, selection, pricing and ordering information can be found quickly and easily. Among the many new features of the Buy Log are: Selector charts for each product type, pictorial descriptions, consolidated pricing tables, and an alpha-numerical listing of all catalog numbers covered in the bulletin.

Also included are ratings, weights, dimensions, standard package quantities, ordering directions and several pages of general application information. General Electric Co.

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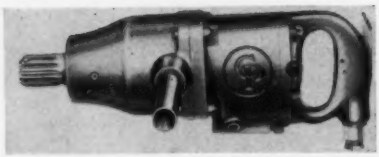

Impact Wrench Handles Big 1 1/2-Inch Bolts With Ease

Designed for erection, modification and equipment maintenance operations, the CP-612 impact wrench with built-in torque control has ample capacity for even the heavy-duty 1½-inch bolts.

The tool has reversible torque control, and features a power saving spline shank. Chicago Pneumatic Tool Co.

Circle E15 green card, last page

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Diethylene Glycol
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For removal of water, hydrogen sulfide and carbon dioxide from natural gas streams—local stocks are available for on-time delivery schedules to fit your processing requirements.

In the Southwest, call Ranger Chemical Company, Houston, Texas, or Western Chemical Company, Odessa and Borger, Texas, and Farmington, New Mexico. Tank car, tank truck, and drum shipments are also available from the Brandenburg, Kentucky, plant.

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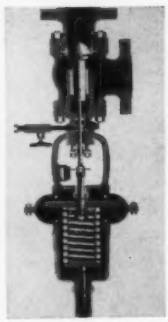
Automatic Asphalt Blending Described In Bulletin

A new bulletin describing a typical Proportioneers Asphalt Blending Installation for the automatic and continuous blending of asphalts has been released. The blender enables direct blending of asphalt and solvent into tank trucks, tank cars, or storage, eliminating excessive tank storage facilities, mechanical mixing, foaming, evaporation of solvent and human errors. This in-line method of blending minimizes fire hazard. In addition, the resultant blend is more uniform and can be duplicated for any number of batches and quantities.

The asphalt blending equipment can be installed at far lower cost than new storage or batch blending tanks. The entire operation is fail-safe with the blender automatically shutting down if proportions are not maintained, or supply fails. The blend of solvent and asphalt is adjustable from 5 to 50 percent solvent with the resultant blend accurate to ½ percent of the setting. The blend rate can be controlled at the loading arm by the operator filling the tank truck or tank car. B-I-F Industries, Inc.

Circle E16 green card, last page

Angle Control Valve Cuts Viscous Fluid Cavitation



A new angle-control valve with an improved venturi effect designed to reduce turbulence and cavitation in the control of slurries, viscous or flashing fluids has just been developed.

Pneumatically operated, the valve has a bolted tailpiece, permitting easy access to the clamped-in seat ring, and a bolted bonnet which permits plug and stem replacement without removal of the body.

A pneumatic diaphragm actuator provides air-to-open or air-to-close valve action. Valves are made of carbon steel and Type 316 stainless steel in sizes from one through six inches with body ratings to 600 pounds. They are available with full capacity or 40 percent capacity trim. Minneapolis-Honeywell Regulator Co.

Circle E17 green card, last page

Data Sheet Covers Quality Control By Chromatograph

The rapid, reliable analysis of petrochemical samples in an expanding petroleum plant is described in a new technical publication.

Application Data Sheet GC-91-0 explains the use of Beckman laboratory Gas Chromatographs for around-the-clock quality control analyses in a large plant producing butadiene, ammonia, ethylene, and ethylene oxide. Through

Revolutionary New Flexible Metal Hose by BREEZE

(PATENTED)

Withstands New Highs in Pressures, Temperatures and Vibration

Where single convolution and synthetic tubing can't do the job, this all-metal hose, formed by BREEZE exclusive DOUBLE convoluting process will solve the most exacting high performance problems. Here are the advanced features:

1. **Excellent flow characteristics — low pressure drop.**
2. **Shorter bending radius — greater flexibility.**
3. **Double convolution design takes higher pressures, minimizes turbulence, absorbs vibration. No "set" due to misshaping of convolutions under high pressures, severe surges and pulsing.**
4. **All metal, high alloy 100% non-corrosive material. Withstands high temperatures where synthetics fail.**

Tell us your applications, requirements in pressures, temperatures, bend radius, inside diameters and usage (fuels, chemicals, oil, gas, etc.) We will fit this premium grade hose to your specific needs.

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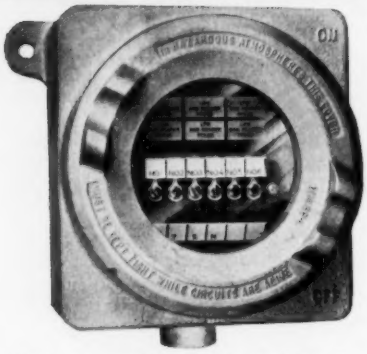
MINIATURIZED...

EXPLOSION-PROOF...

RUGGED...DEPENDABLE

new
SCAMMIT
STATIC-SWITCHING
Model ST-EM
MONITORING
SYSTEM



You only need 6" x 7" to install a 6 point SCAMMIT ST-EM. It's designed for monitoring unattended processes where exact trouble spot must be known and identified. Available in 6 unit assemblies for any explosion-proof alarm. 120 v, 60 cyc.

OTHER MODELS FOR ALL APPLICATIONS in the SCAMMIT line. Self-contained, with permanent components and static switching. Low initial cost, easy installation, less maintenance.

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REPRESENTATIVES IN ALL PRINCIPAL CITIES
COMPLETE MONITORING SYSTEMS FOR INDUSTRY

Equipment . . .

their use, laboratory analytical capacity was increased 400 percent. Beckman/-Scientific & Process Instruments Division.

Circle E18 green card, last page

Pipe Repair Clamp Said To Be Easy, Foolproof

Designated the Style 118 "Handiband", a new repair clamp quickly repairs leaks or breaks in steel piping.

Installation is fast, easy and foolproof. Simply snap clamp around pipe, drop the bolt head through the open-slotted lug and tighten the nut. Compression of a large-size gasket seals the leak completely and permanently. There are no loose parts to lose or to slow installation.

Individual components of the repair clamp are carefully engineered and constructed. Lugs are of rugged malleable iron and are Red "D" Shopcoated for added protection. The Handiband is of stainless steel for greater strength and corrosion resistance. The Grade 42 rubber compound gasket offers superior resistance to all common line contents plus condensates, aromatic and aliphatic hydrocarbons. These gaskets retain their resilience after years of use. Bolts for the Style 118 are cadmium plated for greater strength and longer life.

The Handiband Clamp is available for pipe sizes ½ through 8 inches in 3, 6, 9 and 12 inch lengths. Dresser Mfg. Division, Dresser Industries, Inc.

Circle E19 green card, last page

Filter Design Bulletin Has Been Published

Are you designing a system using a drum filter? If so, a new bulletin has been published giving engineering data and specifications. It includes drawings and descriptive information on the differences between the scraper, string and roll discharge drum filter. Komline-Sanderson Eng. Co.

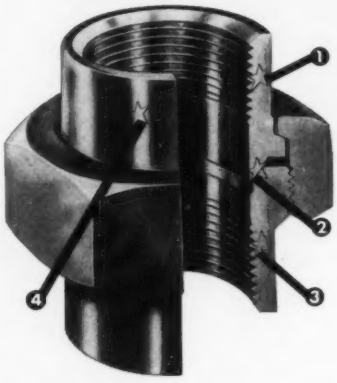
Circle E20 green card, last page

Pushbutton Station Made For Corrosive Resistance

Corrosive resistant, surface mounted, NEMA Type 4 and 5 pushbutton stations and pilot lights are described in literature just released.

Designed to operate successfully under toxic conditions, the surface mounted pushbutton stations consist of molded phenolic enclosure case and cover, neoprene gasket and Type 316 stainless steel hardware components which make them

only
CATAWISSA
gives you all these features for your forged steel pipe union requirements



1. **Uniform walls** for even expansion and contraction under temperature changes. They follow the pipe!

2. **Catawissa Ball-to-Angle Seats** give you a "Perfect Seal" regardless of pipe alignment!

3. **More than adequate** wall thicknesses give you Catawissa's 3-to-1 Safety Factor (3000-lb. service, 9000-lb. test; 6000-lb. service, 18000-lb. test)!

4. **Round, straight barrels** for fast wrenching. No uneven or tapered surfaces to cause wrench slips or wrench locking!

Catawissa Perfect Seal Pipe Unions are made by Union Specialists from 80,000 lb. tensile strength steel (ASTM Spec. A-105-55T, Grade II). Steel forgings from our own forging mill are closely checked for imperfections . . . and finishing on modern, automatic machines with close inspection during and after production give you pipe unions second to none!

Write for Catalog 58 showing the complete Catawissa line of Perfect Seal Products.

for complete, guaranteed satisfaction

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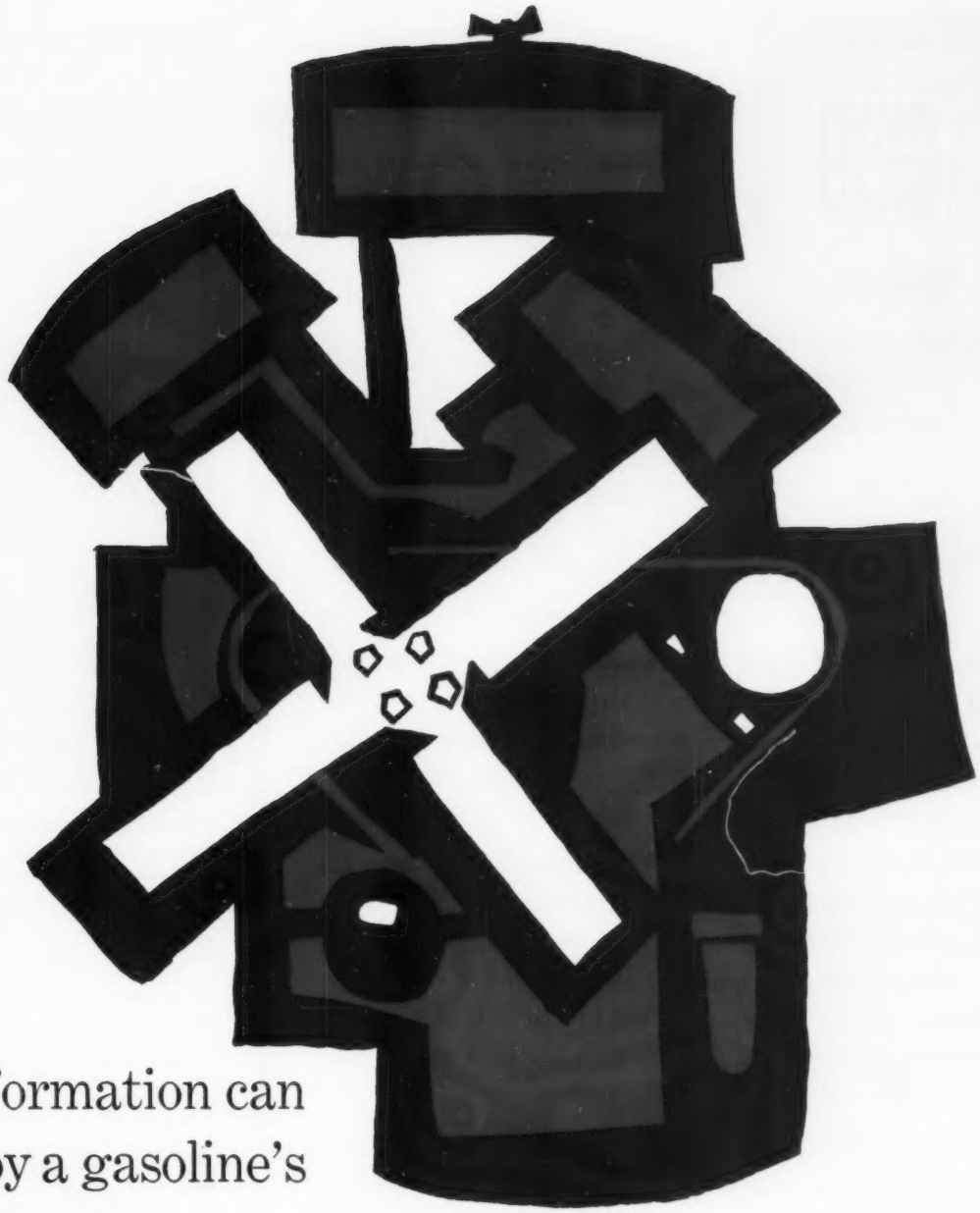

gum formation can destroy a gasoline's good name... protect yours with Tenamene

Eastman gasoline additives

Why Tenamene? *Because* the Tenamene line offers you every principal type of gum inhibitor in commercial use today.

Because Eastman, as a basic manufacturer of the additives it supplies, maintains complete and precise control every step of the way, assuring you of a uniform product and consistent additive performance.

Because Eastman petroleum specialists are available for on-the-spot technical service to make absolutely certain you obtain the most efficient use of the additives you buy. Talk to them, for example, about the economy of bulk delivery.

You'll find Eastman petroleum specialists can give you unequaled technical service because inhibition of gum formation is their only interest. EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

SALES OFFICES: Eastman Chemical Products, Inc., Kingsport, Tenn.; Atlanta; Chicago; Cincinnati; Cleveland; Detroit; Framingham, Massachusetts; Greensboro, N. C.; Houston; New York City; St. Louis. **West Coast: Wilson Meyer Co.,** San Francisco; Denver; Los Angeles; Phoenix; Salt Lake City; Seattle.

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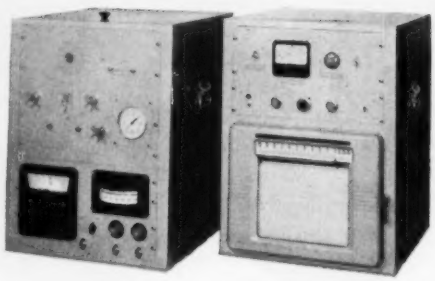
THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

Compact, high-sensitivity system developed for gas chromatography



Model 20 Ionization Detection System uses either capillary or coiled metal columns. Separate cabinet makes column highly accessible for experimentation.

Field-proved design and the newest ideas in chromatography are combined in the Wheelco Model 20. Capillary columns up to 2000 ft long can be used providing the advanced design detector with a sensitivity of 10^{-15} moles, even on short retention time gases such as butane.

With the Wheelco Model 20 a single ionization cell serves as the detector, no reference cell is required. Moderate variations in detector temperature and in flow of carrier gas (usually argon) have negligible effect on the base current. Column temperature is maintained to a $\pm$ .3°C over a continuously variable range from 25°C to 250°C. A cooling coil can be added.

A Wheelco 8000 Series 0-50 MV range, potentiometer-type recorder designed to operate with electrometer amplifier is part of the system. Integrator, with or without digital readout, is an optional accessory.

Wheelco sales and service branches located in all principal cities can provide more details or write to address below. Ask for Bulletin F-9263.

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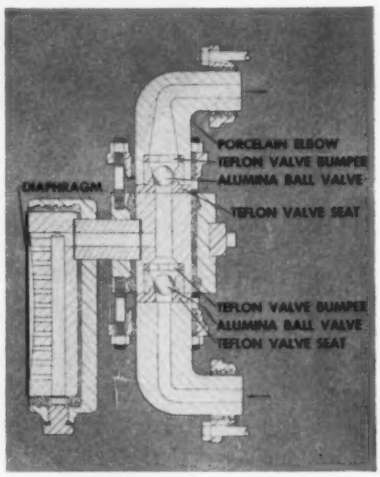
Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Electrical Components • Small Motors • Overdoors and Operators Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

Equipment . . .

impervious to most chemical conditions.

The pushbutton stations are available as a single unit with momentary contacts, two units with momentary contacts, two units with maintained contacts, two units with one momentary and one maintained contact, single unit with pilot light, and two units with pilot light. Allis-Chalmers Manufacturing Co.

Circle E21 green card, last page

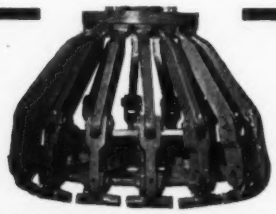


Porcelain Head Converts Pump To Acid Handler

A new chemical-porcelain reagent-head, mounted on a standard Lapp Pulsafeeder controlled-volume diaphragm pump, inexpensively converts the unit into a corrosive liquids handler suitable for any process operations.

The head acts as a transfer medium for corrosive fluids, liquid being drawn into the suction check valve of the head and discharging it out the discharge check valve of the pump by the action of a hydraulically actuated diaphragm.

The use of the chemical-porcelain



BARRETT automatic

Filling and Crimping Equipment

for handling greases and other viscous fluids.

- No operator required.
- 100% air operated.

Fills, seals, stamps and counts lug cover pails. Output of 15 pails per minute. Write for details on installation to meet your requirements.

BARRETT

Manufacturing Co.

P. O. Box 8096, Houston 4, Texas

liquid-contact parts allows the user to handle any acids, except hydrofluoric, at elevated temperatures and most alkalies at moderate temperatures. The porcelain is utilized for the pumping head, connector, valves, valve housing and inlet and outlet connections. These parts are reinforced with metal or fiberglas armor. Versatile Teflon is used for the diaphragm, valve seats, valve stops and gaskets. Lapp Insulator Co.

Circle E22 green card, last page

Hot Corrosive Acids Lubricate Bearings

Hot, corrosive acids act as lubricants for new journal bearings of Pyroceram, the high-strength glass-ceramic.

The bearings are capable of operating with various metal shafts at operational loads under highly corrosive conditions.

Sliding action tests showed that when a Pyroceram bearing part was run against itself or against currently accepted bearing metals, it showed less friction, less wear and less surface damage than other standard bearing materials.

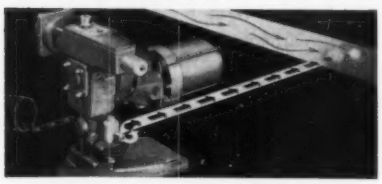
The tests were run by an independent laboratory in several corrosive fluids, including ferric chloride, nitric acid, sodium hydroxide, molten lead (700 F), citric acid, and hydrogen peroxide. Corning said that Pyroceram maintained stable hydrodynamic characteristics, resisting all tendency to weld or score. Corning Glass Works.

Circle E23 green card, last page

Bulletin Covers Steel Valves For Sulfuric Acid

Technical Bulletin 8 describes Aloyco 20, the special austenitic stainless steel recommended for valving sulfuric acid and other severely corrosive liquids. Cross-sectional views show the many Aloyco valve designs available. A graph illustrates the strengths and temperatures of sulfuric acid in which the alloy may be used. Alloy Steel Products Company, Inc.

Circle E24 green card, last page



Metering Pump Proportions Chemicals To Line Flow

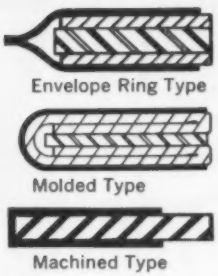
Latest addition to the McCannameter line of metering pumps, the compact and packless Pneumatic Stroke Controlled McCannameter automatically proportions chemicals to any main line flow. Utilizing its pneumatic stroke controlled instrumentation, the pump maintains a

MOST COMPLETE LINE

Eleven Product Groups Serve Every Sealing Need

GROUP NO. 8

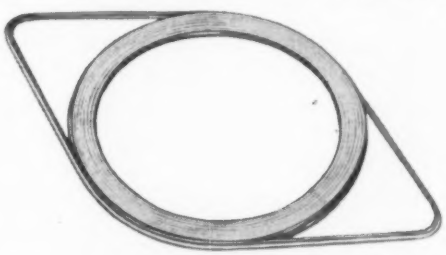
GASKETS

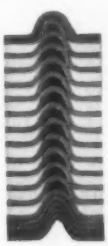


Chemically Impervious TEFLON*

Belmont Teflon Jacketed Gaskets offer special filler materials and inserts which meet specific installation and operating needs with respect to compressibility, resilience and rigidity.

Hence, they protect special chemical piping and equipment against excessive bolt loading while insuring perfect seals between metal, glass, glass-lined, Karbate, Haveg, porcelain, etc.





BELMONT Spiral Wound

Belmont Spiral Wound are gaskets with resilience "built in" for positive sealing action under the toughest service conditions.

Depending upon service, metal is either plated low-carbon steel or stainless. Filler materials are white or blue asbestos, or Teflon.

The Belmont Packing and Rubber Company • Butler & Sepviva Streets, Phila. 37, Pa.

*du Pont Trademark

BELMONT

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Nationwide Industrial Distributor Organization Provides On-the-Spot Service

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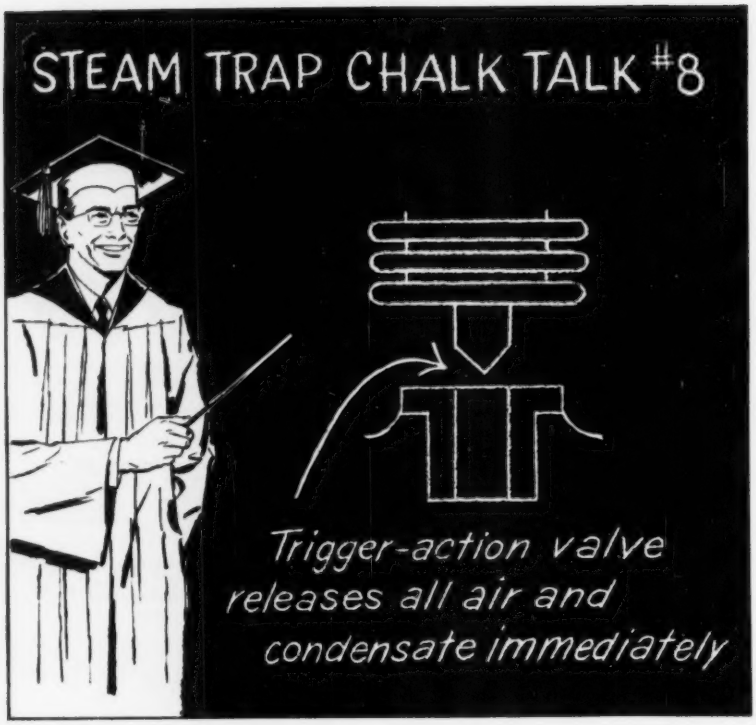
11. Expansion Joints

For more data on advertised products, use Readers' Service Cards, last page.



Why instant condensate drainage is important in refinery applications

- In refinery applications, it's important that all outdoor steam traps discharge air and condensate as soon as it reaches the trap. Outdoor traps must also be capable of draining the steam units and pipelines dry, as well as the trap itself, when steam is shut off to prevent damage from freezing.

Anderson Quik-Flex Steam Traps are designed for this special outdoor refinery use. Companion to well-known Super-Silvertop inverted bucket traps, they feature a trigger-action valve that responds instantly. Guaranteed against freezing for two years, they are the ideal refinery trap.

For complete specifications on Anderson Quik-Flex Steam Traps, mail the coupon today.

A TRAP FOR EVERY PURPOSE

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division of International Basic Economy Corporation
1953 West 96th Street • Cleveland 2, Ohio

Please send without obligation your 36-page steam trap engineering catalog, "How to Select Steam Traps and Other Fluid Specialties".

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ANDERSON QUIK-FLEX

Equipment . . .

constant discharge in proportion to the main line flow. Operating on a 3 to 15 psig air signal, the versatile instrument requires no additional power source of air, responds instantaneously to eliminate backflash and keep chemical-discharge-to-flow ratio precisely accurate. Hills-McCanna Co.

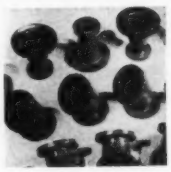
Circle E25 green card, last page

New Hard Facing Process Described In Literature

New descriptive and technical data on the application of hard facing materials by the new sprinkle-fuse process is available. Utilizing alloys in powder form, the new process is said to represent an economical method of applying hard facing alloys of controlled depth and free from slag inclusions, blowholes and shrinkage porosity. The data are illustrations of the method being used on pump and valve points and other equipment where a high degree of resistance to abrasion, corrosion or heat is necessary. Deloro Stellite, Ltd.

Circle E26 green card, last page

Glassed Ductile Iron Fittings Are Very Strong



Glassed ductile iron fittings, available July 1, are 2½ to 3 times stronger than conventional glassed-gray-iron fittings. Thermal shock resistance is markedly increased, according to the manufacturer.

Conventional glassed-gray-iron fittings have been ruled-out for certain types of service because of the danger of rupture due to sudden internal pressure or external impact. The recent development of ductile iron, combined with a glassing technique, overcomes these limitations encountered with glassed-gray-iron fittings. One reason for ductile iron's superior tensile strength of 60,000 pounds minimum is that the graphite is in nodular form, rather than in longitudinal flakes. This eliminates

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Makes Higher Heat Resistant Concrete

Haydite aggregate used with Lumnite cement produces refractory concrete suitable for sustained temperatures up to 1800-2000° F., which makes it excellent for tubular heaters, ducts, flues, stacks and catalytic crackers. Weighing from 30 to 40 per cent less than ordinary aggregate concrete, Haydite is exceedingly strong. It has excellent insulating properties and withstands pressures of up to 1130 pounds per square inch. Write today for free folder and complete information about Carter-Waters Refractory Haydite.
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CONSTRUCTION MATERIALS
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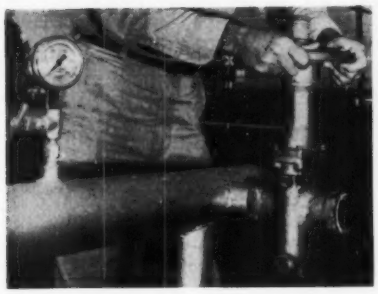
stress concentration areas by equalizing distribution of stress.

In addition to the increased tensile strength, yield strength and thermal shock improvements, the new ductile iron fittings will permit the advantages of glassed-metal construction to be realized in many new applications. Glassed ductile iron possesses similar physical and chemical characteristics to glassed steel—that is resistance to acids except hydrofluoric at temperatures to 350 F, and under specific circumstances to 450 F; resistance to most alkalies at moderate temperatures; resistance to product adherence and easy cleanability.

Standard glassed-ductile-iron fittings are scheduled for July 1 delivery. Included are 45 and 90 degree elbows, tees, and crosses in 1½, 2, 3, 4 and 6 inch sizes. The Pfaudler Co.

Circle E27 green card, last page



Gate Valve Provides Tight Seal With No Lubrication

A new line of pressure sealing gate valves that provide a tight seal both up and downstream and require no lubrication, has just been introduced.

The new valve line is available in the ASA 150 and 300-pound class in a range of sizes from 2 to 12 inches.

The new valve incorporates a full bore and through conduit, seats that automatically adjust for wear, automatic upstream relief for excessive body pressure, and ease of maintenance.

An unusual feature of the valves is the design of the floating seats. Each seat consists of two kinds of rubber, molded to a hardened steel insert ringed with holes. Soft rubber, for sealing, is applied to the back of each seat, and tough, abrasive-resistant rubber on the front or gate side. Pressure forces the soft rubber through the metal insert holes, reinforcing the tough rubber and compensating for any wear on the face of the seat.

The seats provide a double action seal. The tough rubber creates a primary seal against the gate, and as line pressure is increased the gate compresses the rubber ring until the gate rests against the metal insert, providing a metal-to-metal secondary seal. This action forces the soft rubber on the back of the seat into its recess and prevents any downstream flow. The upstream seal is caused by line pressure forcing its way into the seat recess behind the upstream seat moving the seat tightly against the gate.

A neoprene rubber bellows indicator, colored bright yellow for long-range visibility, extends above the handwheel when the valve is open and retracts into the handwheel when the valve is closed. It also protects the stem threads from dirt and corrosion.

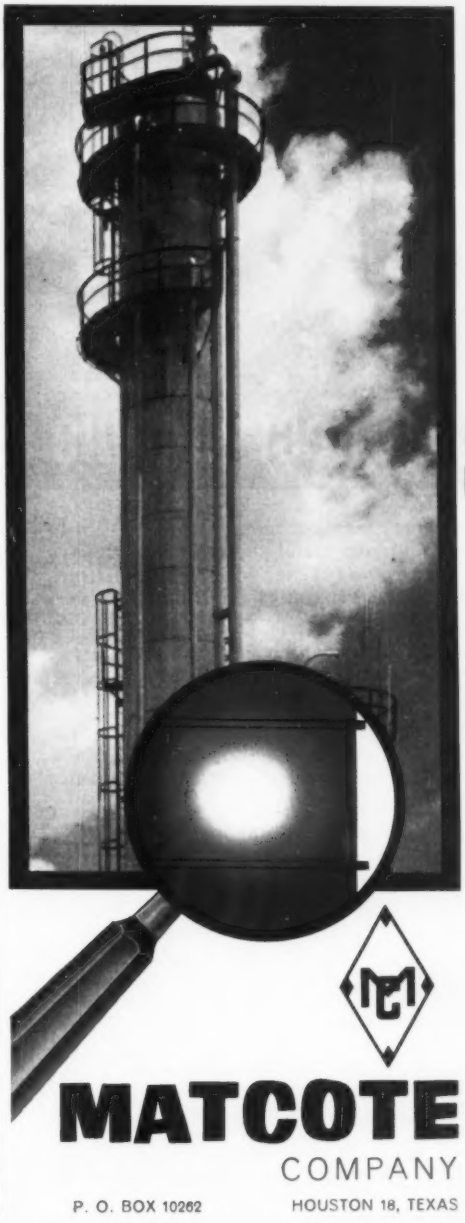
The body and bonnet are cast steel and the stem is heat-treated, hardened stainless steel. The gate is made of steel, hard chrome-plated for protection against wear and corrosion. WKM Division of ACF Industries.

Circle E28 green card, last page

Manual Tells How To Specify Heat Exchangers

Engineers who have occasion to specify heat exchangers will welcome a complete specifications manual on double pipe or hairpin heat exchangers just published.

Called Specifications Manual M-100, this hard-bound reference serves as a guide to the specification writer or engineer who desires to simplify heat exchanger specifications by using a single modular hairpin unit for all duties. Combined in proper series, parallel or series-parallel combinations, as the duty demands, this system by using one standard unit eliminates the delay and expense of designing different heat exchangers



NEW PAINT GIVES VISUAL WARNING OF INTERNAL INSULATION FAILURES

Once applied to the outside skin of the unit, this revolutionary three-color temperature indicating paint serves as a visual warning of any internal insulation failures and also serves as outside protection against corrosion. As temperature rises at any place on the skin, color changes from green to blue to white.

Initial green color turns to blue at 375-400°F.; at 600°F. the blue changes to white and remains white up to 900°F.

Now refineries and chemical plants have a reliable, simple visual warning of internal insulation failures on such equipment as cat-crackers, collectors, reactors, reformers, pressure vessels, hot pipe lines, and heat exchangers . . . without need for pyrometers or temperature sticks.

This new three-color temperature indicating paint, MATCOTE 701, is the only high temperature service coating available which passes through these three color phases to warn of insulation failure.

For detailed information on this and other MATCOTE paint products simply write to the address below on your letterhead, today.

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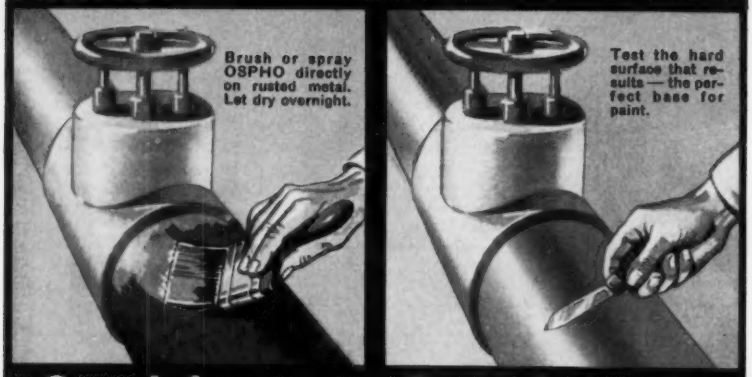
SEE FOR YOURSELF HOW

OSPHO®

PREPARES RUSTED METAL FOR PAINTING...


Brush or spray OSPHO directly on rusted metal. Let dry overnight.
Test the hard surface that results — the perfect base for paint.

Send for FREE Test Sample

Eliminate sand-blasting or flame-cleaning. Simply brush off loose rust and apply OSPHO on the rusted metal surface. One application *kills* the rust and provides a *sound* base for your regular maintenance paint. Rust action is stopped — paint jobs last much longer.

OSPHO is *not* a primer — *not* a paint. It is a carefully balanced phosphate chromate metal treatment which chemically changes rust (iron oxide) into iron phosphate — an inert, hard, gray surface ideal for painting.

OSPHO provides excellent coverage . . . a gallon treats up to 600 square feet. And cost is low. Available in 1-gallon containers (in cases of 4), 5-gallon pails, 50-gallon barrels. Colorless, non-toxic, non-flammable. Available through distributors.

Repeat orders over the past 16 years are proof of OSPHO's effectiveness. *See for yourself . . .*

Write Now For FREE Test Sample
(on company letterhead)
and descriptive literature

TREATS NEW METAL TOO!
When applied on new ferrous metal, galvanized iron and aluminum, OSPHO imparts a slight etch to the metal, insuring tight bond of the paint coat that follows.

ONLY OSPHO KILLS THE RUST

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Equipment . . .

for each duty. This high flexibility eliminates the possibility of obsolete heat exchangers, as changes in duties are met easily and quickly on short notice by simply rearranging the modular units.

Standardization on one unit reduces stores and parts to one set, and makes for easier maintenance since only one type of exchanger must be serviced.

A well-indexed manual, it is broken down into seven major sections. In addition to the general specifications which cover scope, codes, guarantees and drawings, there are sections on design, materials, welding procedure, testing, inspection and stamping and preparation for shipment.

Sub assembly drawings are incorporated into the back of the manual so that the engineer has everything in one volume necessary for the detailing and writing of a standard modular heat exchanger system. Brown Fintube Co.

Circle E29 green card, last page

Light Wall Stainless Steel Fittings For 150# Service

A new line of light-wall stainless steel fittings and flanges designed for nominal-temperature, low-pressure non-critical process piping has been developed.

The new line, called "Pipe-Mate," will be stocked in ½ through 4 inch sizes, Schedule 5S and 10S, in the stainless steels grades best suited to corrosive applications in the large middleground area of roughly 150 psi or less.

Introduction of the low-cost Pipe-Mate line is a logical extension of the trend by chemical process and other industries toward the money-saving use of lighter-than-standard weight pipe and fittings for non-critical service.

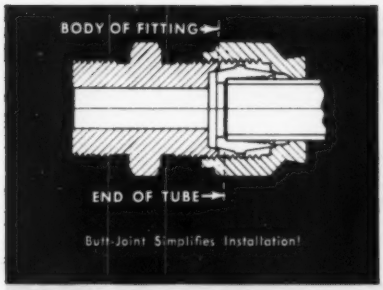
A special feature is a novel swivel-type insert flange especially designed for ease of alignment. It is a carbon steel flange, and it has a stainless steel insert at the bore into which pipe or fitting can be expanded, then the carbon steel portion is simply rotated to line up the bolt holes and tightened. No welding is involved. Another feature of the new line is a reversible fitting called the "Plug-R-Cap." Butt welded in regular position it is a

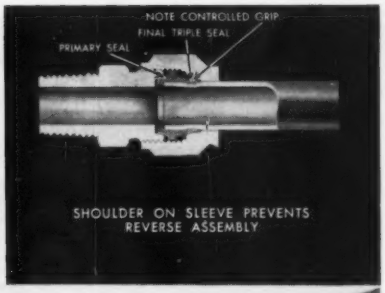
ABILITY

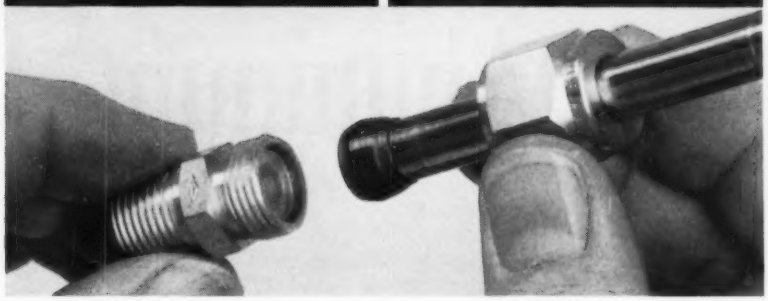
SACHSE ELECTRIC INC.
BATON ROUGE LA.

IMPERIAL *Engineering and Data File*

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS







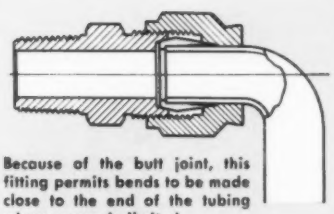
How Hi-Seal tube fitting design simplifies refinery piping

The butt-joint feature of Hi-Seal fittings is a design consideration acclaimed by fitting users throughout industry. The tube *does not* enter body of fitting! It bottoms on the shoulder of the sleeve. This butt joint feature makes possible far more compact piping layouts than other fittings.

Users have obtained these benefits: (1) cuts space requirements up to 50%; (2) reduces number of bends required; (3) cuts man hours and installation time; (4) substantially reduces the amount of tubing needed. Hi-Seal provides added benefits on copper tube installation by permitting the use of straight lengths of .028" copper tubing in bending temper instead of .032" soft tubing in coils, ends the need for straightening.

FOOLPROOF ASSEMBLY — Anyone can make leakproof connections with Hi-Seal fittings. There is only one way to assemble the Hi-Seal fitting . . . only one way tubing can go into sleeve . . . only one way sleeve can go into fitting.

Hi-Seal design also makes maintenance of equipment easier through quicker disassembly and assembly of joints — may be disconnected and reconnected as often as desired.



Because of the butt joint, this fitting permits bends to be made close to the end of the tubing where space is limited.

COMPLETE LINE — Hi-Seal fittings are available in brass, steel, stainless steel. Also can be furnished in Titanium, Tantalum and other metals. Steel fittings supplied with cadmium plate or black phosphate finish. Conform to J.I.C., A.S.M.E. and A.S.A. standards. In sizes for ⅛" to 1½" O.D. tubing. Furnished with Long Dryseal pipe threads or straight thread port seal.

Write for Bulletin No. 3061

New high-pressure valves assemble directly to tubing, eliminate additional fittings

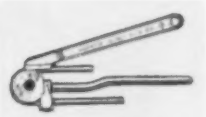
A revolutionary new line of Imperial needle valves designed for working pressures up to 5,000 psi., and temperatures to 450° F., employs Hi-Seal tubing connections.

These valves attach directly to tubing and eliminate additional fittings. This not only reduces cost but cuts installation time and eliminates principal source of leakage.

For low pressure service, Imperial also supplies a complete line of fluid control valves in diaphragm, plug, (2, 3, and 4-way styles) — needle and toggle types.

Write for Bulletin 3096, or Catalog No. 200

Dimensional Bends easily made with Imperial Blue Dot Benders



It's no trick to make bends at any desired point — that conform to dimensional requirements as to developed tube length and location — when you use Imperial Blue Dot Benders. Full instructions with each bender.

Imperial Benders are of the open side type. They slip over the tubing where the bend is desired — handy in hard-to-get-at places or when tubing has one end connected.

They form neat, accurate bends on hard or soft tubing without annealing. Calibrated for bending any angle up to 180°.

Wide range of individual and combination benders for 2 to 7 sizes — from ⅛" to ⅞" O.D. (⅛" to ¾" nom.).

Write for Bulletin No. 3088

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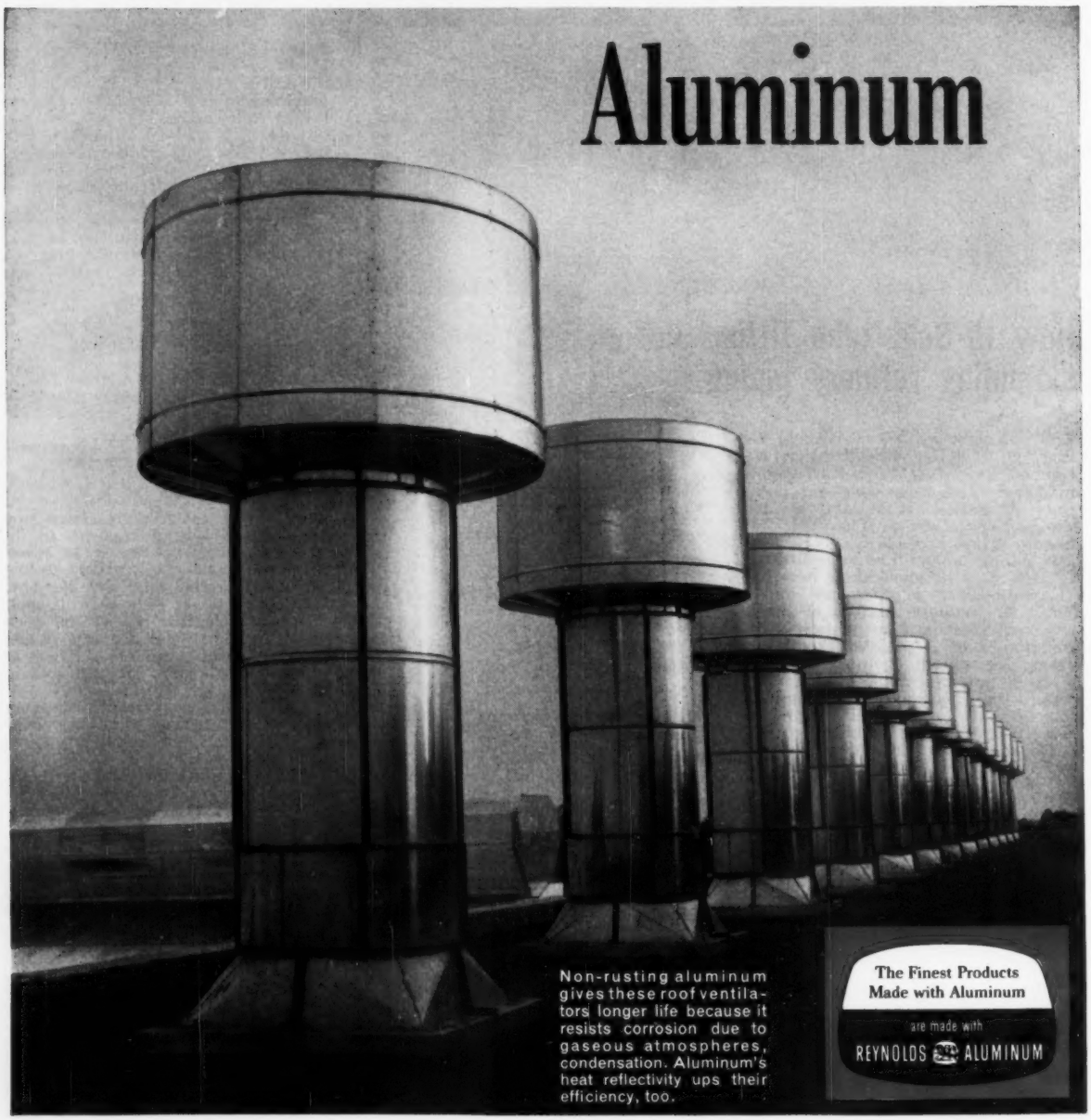
... Non-Rusting, Corrosion-Resisting


Aluminum
Non-rusting aluminum gives these roof ventilators longer life because it resists corrosion due to gaseous atmospheres, condensation. Aluminum's heat reflectivity ups their efficiency, too.
The Finest Products Made with Aluminum
are made with
REYNOLDS ALUMINUM

For more data on advertised products, use Readers' Service Cards, last page.

Reynolds Aluminum Improves Plant Appearance, Lowers Installation and Maintenance Costs

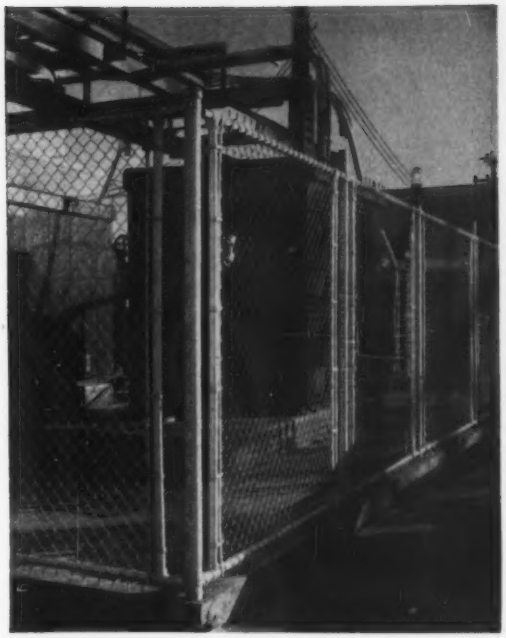
You can build low maintenance and lasting good looks right into a plant or equipment—by using strong, lightweight, rustfree aluminum in structural and building applications. Aluminum resists corrosion due to weather and gaseous atmospheres, so it needs little or no attention in a processing or refining plant installation. It can't rust ever, and it stays strong and new-looking, even in damp and corrosive places.

And maintenance costs aren't the only costs that can be lower, when you build with aluminum. Aluminum is the *lowest cost corrosion-resistant metal*, and its light weight (⅓ the weight of steel) can speed installation, cut building labor.

Thus, a catwalk using Reynolds Aluminum treadplate is not only maintenance-free—it often can be put up faster, at less cost than any other corrosion-resistant structure. Roof ventilators made with aluminum resist corrosion and won't rust—and, because of aluminum's heat reflectivity, are often more efficient. Aluminum chain link fencing never needs painting for protection, seldom needs maintenance of any kind.

Cost-cutting Reynolds Aluminum is finding its way into more and more applications in chemical and petroleum processing, not only in building and structural uses, but in piping, jacketing, heat exchangers, and other process equipment.

Before you plan your next installation, check *all* the costs, and learn how aluminum can save for you. For details, contact your local Reynolds office or write direct to *Reynolds Metals Company, P. O. Box 2346-CT, Richmond 18, Virginia.*



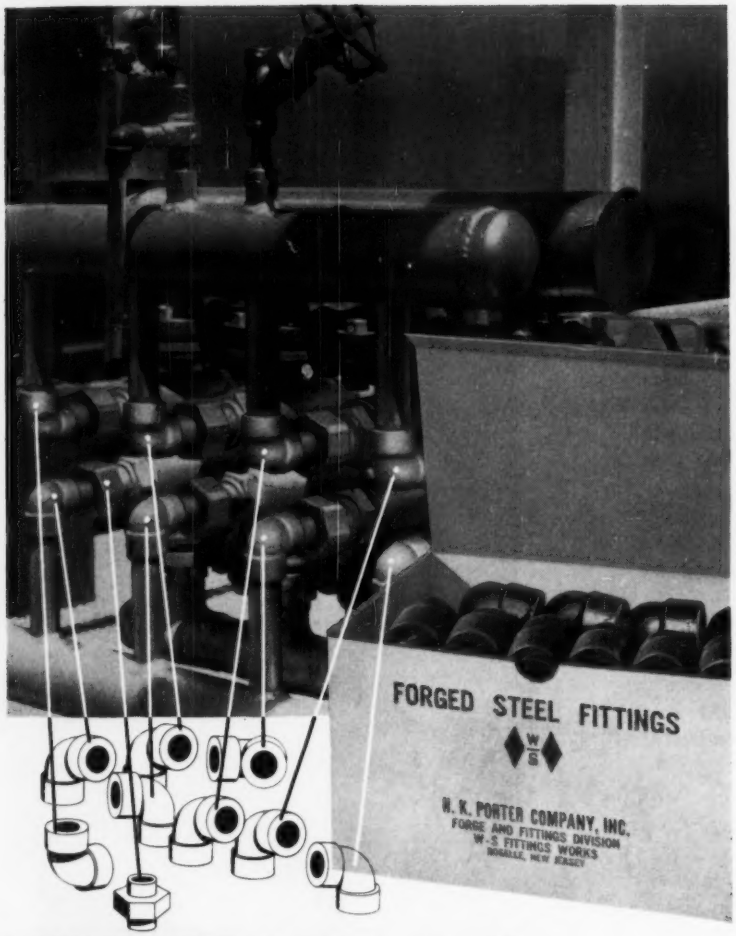
This fence will never need protective painting, seldom need any maintenance at all.

Upkeep on this stairway and conveyor is just about zero; aluminum stays bright and new looking, and it's non-sparking.

REYNOLDS ALUMINUM

Watch Reynolds TV show "WALT DISNEY PRESENTS" every week on ABC-TV

For more data on advertised products, use Readers' Service Cards, last page.



FORGED for long life
PACKAGED for convenience

The "Forged" in W-S Forged Fittings means dependability under the toughest piping-job conditions. "Forged" gives you the added resistance to pressure, heat, corrosion, shock and vibration needed to make your installations long-lived and safe. And W-S Fittings are easily installed, with tight fits and perfect alignment . . . thanks to W-S precision machining methods and quality forging techniques.

Packaging, too, is a W-S brand advantage. Virtually any "mix" of fitting types and sizes can be packed in a convenient W-S Case or Half-case . . . each type and size in its own carton.

Specify W-S on your next order. For specifications and Distributor locations, write *Forge and Fittings Division, H. K. Porter Company, Inc., Box 95, Roselle, New Jersey.*

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Equipment . . .

cap. Reversed, it can easily fillet welded to act as a plug or pipe closure.

The fittings can be butt welded in the normal manner or, with the use of an alignment connector or sleeve they can easily be fillet welded or brazed. Where flanged connections are desired, the pipe or fittings are simply expanded into the bore of the flange insert and no welding is required. Tube Turns Division of Chemetron Corp.

Circle E30 green card, last page

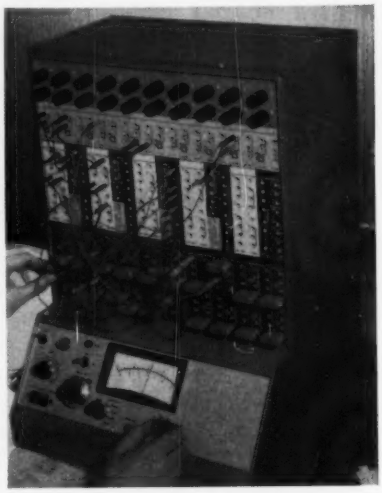

Table Top Computer Solves Daily Engineering Problems

A low-cost analog computer capable of performing 95 percent of the routine mathematical operations encountered by an engineer in normal design calculations has been developed.

Known as the PACE TR-10, the new and completely transistorized computer is 15 inches wide and 17 inches deep and 24 inches high and weighs only 80 pounds without accessories. It occupies little more desk top area than a standard electric typwriter.

The compact size of the TR-10 computer, plus its reliability and accuracy (0.1 percent) was made possible by the company's design and development of a new transistorized DC amplifier.

By applying the advantages of analog computation to the solution of every-day problems, the individual engineer can eliminate to a great degree the frustrations of multiple calculations and multiply his output many times. This new computer places analog computation at every engineer's finger-tips and permits him to obtain first look solutions, especially on dynamics problems, in a fraction of the normal time requirement.

The price of the new computer starts from under $4,000. Read-out equipment, such as plotters and recorders, range in price from $1,350 to $1,900. The exact type of accessory needed will depend on whether the user wants his problem

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Equipment . . .

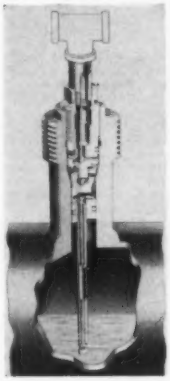
solution presented numerically or in graphic form.

The engineer using the TR-10 computer can order it with a wide choice of computing component combinations to meet his particular problem solving requirements. Electronic Associates, Inc.

Circle E31 green card, last page

Product Sampler Tool Can Be Fitted With Coupons

A simplified corrosion survey instrument for taking product samples under full pressure and normal operating conditions has just been placed on the market.



The product sampler consists of an access fitting body whose bore has a tapered seat and a set of fine machined threads to accommodate a stainless steel gage carrier plug. The lower end of this plug accommodates a specially designed blocking and packing nut, also of stainless steel construction, from which the hollow sampling tube is suspended. (See illustration.)

To prevent product samples from being inadvertently taken from the top of the line, the packing nut is fitted with an O-ring seal. The entire access fitting assembly is secured to the line by means of a threaded, welded or flanged connection.

In operation, pressure forces the line fluid (or gas) through the entry ports of the sampling tube and past the narrow annular space between the tapered seat and the gage carrier plug. The product then passes through a series of by-pass holes into the hollow top bore of the plug and is conveyed to the surface, where it is recovered for analysis.

The product sampler also functions as a dual-purpose instrument, since it can easily be converted to a coupon survey tool of the non-insulated tube type. For use as a corrosion coupon, the regular product sampler tube is replaced with a special sampling tube or rod-type coupon that has been polished and weighed with an accuracy in grams to four decimal points. Cosasco Division; Perfect Circle Corp.

Circle E32 green card, last page

ERRATA

The April issue, page 319, reported a new valve being manufactured by "Hammer Valves, Inc". Actually, the firm is Hamer Valves, Inc. For more information on this product, circle E 33, green card, last page.

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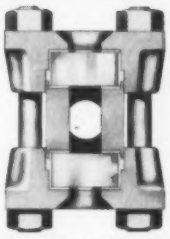

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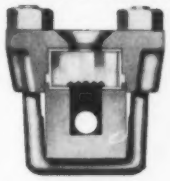

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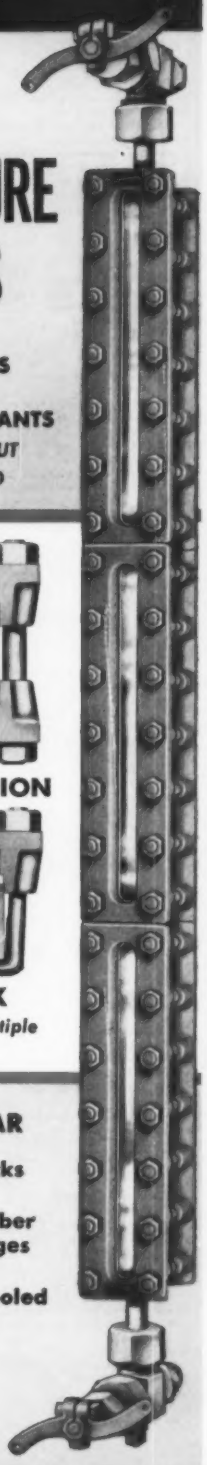

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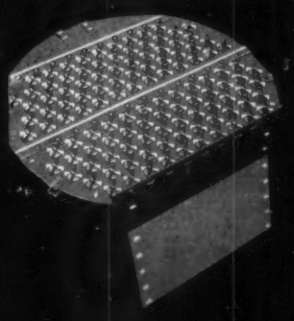

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